UNIVERZA V LJUBLJANI
BIOTEHNIŠKA FAKULTETA

Mojca SIMČIČ

FENOTIPSKE IN GENETSKE ZNAČILNOSTI CIKASTEGA GOVEDA

DOKTORSKA DISERTACIJA

Ljubljana, 2015

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DOKTORSKA DISERTACIJA

PHENOTYPIC AND GENETIC CHARACTERISATION OF CIKA CATTLE

DOCTORAL DISSERTATION

Ljubljana, 2015

Ne preživi najmočnejša vrsta,

niti najbolj inteligentna;

preživi tista, ki se najbolje prilagaja spremembam.

Charles Darwin (1809 – 1882)

Na podlagi Statuta Univerze v Ljubljani ter po sklepu Senata Biotehniške fakultete in sklepa Komisije za doktorski študij Univerze v Ljubljani, z dne 19. 9. 2012 je bilo potrjeno, da kandidatka izpolnjuje pogoje za opravljanje doktorata znanosti na Interdisciplinarnem doktorskem študijskem programu Bioznanosti, znanstveno področje Znanost o živalih. Za mentorja je bil imenovan prof. dr. Dragomir Kompan ter za somentorja doc. dr. Gregor Gorjanc.

Delo je bilo opravljeno na Biotehniški fakulteti, Oddelku za zootehniko na Katedri za znanosti o rejah živali in na Katedri za genetiko, animalno biotehnologijo in imunologijo. Poskus pitanja bikov je bil izveden na Pedagoško raziskovalnem centru Logatec. Podatki za analizo lastnosti zunanjosti so bili pridobljeni iz Centralne podatkovne zbirke Govedo na Kmetijskem inštitutu Slovenije. Statistične obdelave podatkov za genetsko karakterizacijo so bile narejene na Universiteit Utrecht, Faculteit Diergeneeskunde v Utrechtu na Nizozemskem, na Universität für Bodenkultur (BOKU) Wien, Department für Nachhaltige Agrarsysteme, Institut für Nutztierwissenschaften na Dunaju v Avstriji in na Ludwig-Maximilians-Universität München, Tierärztliche Fakultät, Lehrstuhl für Tierzucht und Allgemeine Landwirtschaftslehre v Münchnu v Nemčiji.

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Datum zagovora: 11. 5. 2015

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AI Glavni namen doktorske disertacije je bil proučiti cikasto govedo kot edino slovensko avtohtono pasmo govedi iz različnih vidikov. Z analizo lastnosti zunanjosti smo dokazali, da nanje vpliva več dejavnikov okolja, kar lahko povzroči nepravilno razvrstitev živali v ustrezen tip. Prvič so bili ocenjeni dednostni deleži za lastnosti zunanjosti pri cikastem govedu, ki smo jih uporabili tudi za genetsko vrednotenje. Prvič ocenjene plemenske vrednosti omogočajo pravilnejšo razvrstitev živali v ustrezen tip, kar lahko uporabimo za učinkovitejšo selekcijo populacije z vidika ohranjanja avtohtonih lastnosti. Z genetsko karakterizacijo na osnovi različnih genetskih označevalcev smo prvič dokazali, da je cikasto govedo avtentična slovenska avtohtona pasma in našli možnost za reševanje avtohtonega genetskega ozadja. V skladu z novo klasifikacijo pasem na osnovi genetske raznolikosti, geografske bližine in zgodovine pasme je bilo cikasto govedo prvič razvrščeno v skupino »Centralno-evropsko govedo« in v podskupino »Centralno-vzhodne pasme«, kamor sta razvrščeni tudi pincgavsko in pustariško govedo. Cika bo, na podlagi genetske karakterizacije, kot avtentična avtohtona pasma tudi prvič predstavljena v novi enciklopediji pasem govedi, ki jo pripravljajo na Univerzi v Lincolnu v Veliki Britaniji. Cika je kombinirana pasma, ki so jo v preteklosti redili v glavnem za prirejo mleka. S prvimi poskusi pitanja mladih bikov cikastega goveda smo potrdili, da je pasma povsem primerna tudi za prirejo mesa. V poskusu pitanja skupaj z lisastimi biki so dosegli podobno dobro klavno kakovost in kakovost mesa. Cika je slovenska kulturna dediščina in edinstven genetski vir, ki si tudi na podlagi novih ugotovitev v doktorski disertaciji, zasluži primeren način ohranjanja.

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AB The main objective of the present dissertation was to survey Cika cattle from different aspects. Cika is at present considered as the only Slovenian autochthonous cattle breed. With the analysis of Cika cattle type traits it has been proven that these traits are affected by several environmental effects, which could lead to misclassification of animals in the appropriate type. For the first time, the estimated heritabilities for type traits in Cika were determined and also used for the genetic evaluation. Thus, first estimated breeding values allow adequate classification of animals in the appropriate type, which can from now on be used for more efficient selection of the population in terms of preserving autochthonous traits. The genetic characterization based on different genetic markers demonstrated Cika for the first time in history as an authentic Slovenian autochthonous breed. In this respect, the possibility to rescue autochthonous genetic background was found as well. In accordance with the new breed classification based on the genetic diversity, geographical proximity and breed history Cika has been classified in the group of "Central-European cattle" and the subgroup "Central-Eastern breeds" along with Pinzgauer and Pustertaler cattle. Based on the genetic characterization Cika as an authentic autochthonous breed, will be presented for the first time in a new encyclopedia of cattle breeds published by the University of Lincoln, UK. Cika is regarded as a dual-purpose breed. In the past it was mainly used for milk production. Later on, first fattening trials confirmed that young Cika bulls are quite suitable for beef production as well. In the fattening trial together with Simmental bulls, they achieved similarly good carcass and meat quality. Cika can be ranked among the Slovenian cultural heritage, and is a unique genetic source, which also due to new findings in the present dissertation deserves a suitable conservation program.

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KAZALO PRILOG

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Priloga B: Obrazec za ocenjevanje zunanjosti plemenskih bikov cikastega goveda

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OKRAJŠAVE IN SIMBOLI

CPZ	Centralna podatkovna zbirka
DHA	dokozaheksaenojska kislina (*angl. docosahexaenoic acid*)
DNK	deoksiribonukleinska kislina (*angl. deoxyribonucleic acid*)
DPA	dokozapentaenojska kislina (*angl. docosapentaenoic acid*)
EPA	eikozapentaenojska kislina (*angl. eicosapentaenoic acid*)
EXT	ekstenziven krmni obrok
FAO	Organizacija združenih narodov za prehrano in kmetijstvo (*angl. Food and Agriculturae Organization of the United Nations*)
GLM	splošni linearni model (*angl. Generalized Linear Model*)
ISAG	Mednarodno združenje za genetiko živali (*angl. International Society for Animal Genetics*)
ICAR	Mednarodni komite za kontrolo proizvodnje živali (*angl. International Committee for Animal Recording*)
MUFA	enkrat nenasičene maščobne kisline (*angl. monounsaturated fatty acids*)
n-3/n-6PUFA	razmerje med ω-3 in ω-6 večkrat nenasičenimi maščobnimi kislinami
PRC	Pedagoško raziskovalni center
REML	metoda omejene največje zanesljivosti (*angl. Restricted Maximum Likelihood*)
PUFA	večkrat nenasičene maščobne kisline (*angl. polyunsaturated fatty acids*)
SFA	nasičene maščobne kisline (*angl. saturated fatty acids*)
SIR	Služba za identifikacijo in registracijo živali
S-INT	srednje intenziven krmni obrok
SNP	polimorfizem na posameznem nukleotidu (*angl. Single Nucleotide Polymorphism*)
WB	Warner-Bratzlerjeva strižna sila

SLOVARČEK

Alel – oblika gena ali označevalca na nekem lokusu

A kategorija – biki do starosti 24 mesecev, mladi biki

B kategorija – biki starejši od 24 mesecev, starejši biki

Bos indicus – indijsko govedo, zebu govedo, govedo z grbo

Bos taurus – evropsko govedo, govedo brez grbe

Bos taurus brachyceros – kratkorožno govedo

Bos taurus brachycephalus – govedo s kratko glavo

Bos taurus longifrons – govedo z dolgim čelom

Bos taurus frontosus – govedo s široko glavo

BovineSNP50 Genotyping BeadChip – čip za genotipizacijo goveda, ki vsebuje 54.609 zelo informativnih SNP-ov enakomerno porazdeljenih po celotnem genomu pri glavnih pasmah govedi in se uporablja za genomsko selekcijo, identifikacijo lokusov za kvantitativne lastnosti, vrednotenje plemenskih vrednosti in za primerjalne genetske raziskave.

Dednostni delež – je delež genetske variance v fenotipski varianci za določeno lastnost v neki populaciji; tudi heritabiliteta

Difiletsko poreklo – vrsta, ki naj bi nastala kot potomec prednikov dveh različnih vrst

Druga pašna sezona – pašna sezona po končanem prvem zimskem obdobju življenja živali

EUROP klasifikacija – razvrščanje klavnih trupov v kakovostne razrede na koncu linije klanja na podlagi mesnatosti in zamaščenosti

Fenotip – so morfološke, fiziološke ali opazovane lastnosti nekega organizma, ki jih določa genotip v povezavi z okoljem

Filogenija – je sorodstveno razmerje skupin organizmov glede na evolucijsko preteklost

Genetski označevalec – fenotipski, biokemijski ali DNK polimorfizem, ki ga uporabljamo za opis osebka ali populacije

Genetska raznolikost – je raznolikost alelov ali genotipov, ki so prisotni v proučevani skupini

Genetska razdalja – je merilo za oddaljenost dveh populacij ali dveh vrst na podlagi alelnih zamenjav na lokusih, ki so nastale v toku ločene evolucije

Genotip – skupek vseh podedovanih lastnosti nekega organizma, razpoznavnega po njegovi zunanjosti ali fenotipu; tudi stanje alelov na enem ali več lokusih nekega organizma

Genotipizacija – proces ugotavljanja genotipa posameznika, pri katerem se lahko ugotavlja genotip enega ali pa večih genov

Haplotip – je skupina med seboj tesno povezanih genov, ki se navadno dedujejo skupaj

Križanje – parjenje genetsko različnih osebkov (pasem) nasprotnega spola

Mikrosatelitni označevalci, mikrosateliti – genetski označevalci za populacijske študije, ki omogočajo proučevanje genetske strukture populacij, pretoka genov in učinka ozkega grla; so segmenti DNA, ki vsebujejo ponovitve nukleotidnih motivov dolžine od 1 do 6 baznih parov

Molekularna genetika – veja genetike, ki proučuje sestavo in delovanje genov na molekularni osnovi

Monofiletsko poreklo – pomeni, da se je ena ali več vrst razvila iz enega samega skupnega prednika. Domače živali imajo praviloma monofiletsko poreklo, kar pomeni, da je bila udomačena ena sama divja vrsta

Oplemenjevanje – vnašanje boljših lastnosti ene pasme v drugo pasmo

Plemenska vrednost – vsota aditivnih učinkov genov za določeno lastnost

Pretapljanje – vnašanje lastnosti ene pasme v drugo pasmo dokler druga pasma povsem ne prevzame vnesenih lastnosti

1 PREDSTAVITEV PROBLEMATIKE IN HIPOTEZE

Cikasto govedo ali cika je danes slovenska avtohtona pasma. Rejski cilj je ohranjanje pasme v prvotnem tipu in preprečevanje parjenja v sorodstvu. V preteklosti je bilo to govedo razširjeno predvsem v Alpah in predalpskem svetu sedanje Slovenije. Danes je cikasto govedo razširjeno skoraj po vsej Sloveniji. Po podatkih Službe za identifikacijo in registracijo (SIR) je bilo v juniju 2014 v Sloveniji 3.351 živali cikastega goveda. V centralni podatkovni zbirki (CPZ) Govedo na Kmetijskem inštitutu Slovenije je bilo v decembru 2014 v rodovniški knjigi za cikasto govedo vpisanih 2.021 čistopasemskih plemenic, od katerih jih je bilo 379 v glavnem razdelku rodovniške knjige. Število živali in število kmetij, ki redijo to pasmo, se v zadnjih letih povečuje. Največ rej je na Gorenjskem (okolica Kamnika, Bohinj in Zgornjesavska dolina), v Zgornji Savinjski dolini in v Zgornjem Posočju. V juniju 2014 so cikasto govedo redili na 949 kmetijah v Sloveniji.

Razvoj cikastega goveda je bil na podlagi pisnih zgodovinskih virov podrobno proučen v doktorski disertaciji (Žan Lotrič, 2012). Tukaj navajamo le nekaj prelomnic pri razvoju te pasme. Govedo na Kranjskem je bilo prvič popisano 1872 leta kot govedo brez posebnega imena, rumene, rdeče, rdečerjave in rjavočrne barve. Govedo je bilo majhno zaradi skromnih rejskih in krmnih razmer (Schollmayr, 1873). V letu 1878 je bilo opisano bohinjsko govedo (Hitz, 1878), rjavordeče barve z lepim telesnim okvirom, tankih kosti in z relativno veliko mlečnostjo. Bohinjsko govedo so nekateri rejci že takrat oplemenjevali z biki belanskega goveda (Mölltaler) iz Belanske doline v deželi Koroški takratne Avstro-Ogrske monarhije. Veliko število rejcev pa je še naprej vztrajalo pri uporabi bohinjskih bikov.

Na Gorenjskem je Povše (1893) opisal rdeče pisano gorenjsko govedo, ki je po opisu najbolj podobno cikastemu govedu kot ga poznamo danes. Poleg tega je opisal tudi skromno in mlečno bohinjsko govedo, ki ga ni imenoval kot posebno pasmo. V Posočju je Povše (1894) opisal tolminsko in bovško govedo kot lažji tip belanskega goveda z veliko mlečnostjo. V tistem času je potekalo intenzivno trgovanje z govedom med različnimi deželami Avstro-Ogrske monarhije. Bohinjske krave so bile cenjene kot dobre molznice na Koroškem in na Salzburškem (Žan Lotrič, 2012), bovške krave pa so prodajali v Belansko dolino.

Belansko govedo je imelo relativno majhen telesni okvir, temnejšo rdečo osnovno barvo plašča in zelo dobro mlečnost, a je bilo leta 1925 priključeno k pincgavskemu govedu in je tako izumrlo (Sambraus, 1999). To koroško deželno govedo je dominanten barvni vzorec prenašalo na potomstvo. Ko je prvotno enobarvno lokalno govedo ob koncu 19. stoletja od belanskega goveda prevzelo barvni vzorec, so ga poimenovali cikasto govedo. Po barvnem vzorcu je bilo podobno belanskemu govedu, po telesnih oblikah pa prvotnemu lokalnemu govedu (Ferčej, 1947). Slovelo je po dobri mlečnosti in primernosti za pašo na strmih visokogorskih pašnikih. Sistematično in organizirano rejsko delo, vodenje rodovniške knjige in kontrola mlečnosti je bila pri cikastem govedu uvedena že leta 1906 (Ovsenik, 1926). Leta 1935 so bila v Službenem listu kraljevske banske uprave dravske banovine kot Banova uredba objavljena »Navodila za presojo barvnih znakov cikastega goveda« (Navodila za presojo…, 1935).

Po letu 1935 so za namen oplemenjevanja cikastega goveda začeli uvažati bike pincgavskega goveda iz Avstrije, katerih je bilo na slovenskem ozemlju največ v času druge svetovne vojne. Napredni rejci v dolinah so uporabljali te bike, da bi povečali telesni okvir in s tem prirejo pri cikastem govedu, ki je takrat štelo 58.000 glav (Žan Lotrič, 2012). Rejci na hribovskih kmetijah so zavrnili pincgavske bike zaradi težkih telitev in velike porabe krme pri njihovih potomcih. Posledično sta se oblikovala dva različna tipa cikastega goveda, večji »ravninski« in manjši »planinski« ali »Bohinjski« tip (Ferčej, 1947).

V času po drugi svetovni vojni je bilo v Sloveniji okoli 80.000 glav cikastega goveda (Čepon in sod., 1999). To pasmo so rejci uporabljali zlasti za prirejo mleka in za predelavo le-tega v sir. Na območjih, kjer je prevladovalo cikasto govedo, naj bi bila teleta neprimerna za intenzivno prirejo mesa, zato je bilo leta 1964 sklenjeno, da se cikasto govedo na Gorenjskem pretopi z lisastim govedom. Na Kamniškem in Domžalskem območju se je pretapljanje cikastega z lisastim oziroma z rjavim govedom začelo že prej. Na Tolminskem so cikasto govedo zamenjevali z rjavim govedom. Pretapljanje z lisastim govedom in zamenjava z rjavim govedom sta bili uspešnejši na kmetijah v dolini. Tako so, najbrž, z lisastim govedom pretopili in z rjavim govedom zamenjali povečini že oplemenjeno cikasto govedo s pincgavskim govedom.

Manjše število rejcev je še naprej uporabljalo licencirane bike cikastega goveda za naravni pripust. Takšni pripusti po letu 1976 niso bili več dovoljeni, a so nekateri rejci nadaljevali s pripusti z nelicenciranimi biki cikastega goveda in tvegali kazen. Za osemenjevanje je bilo po letu 1976 na razpolago seme uvoženih bikov pincgavskega goveda in seme bikov križancev s 25 - 50 % genov cikastega goveda in 50 - 75 % genov pincgavskega ali rdečega holštajnskega goveda (Jeretina, 2004).

Tako je bila reja cikastega goveda skoraj 40 let brez načrtnega selekcijskega dela. Število živali cikastega goveda se je zmanjševalo do leta 1992, ko je bilo v registru govedi na Kmetijskem inštitutu Slovenije le še 59 krav, večinoma križank med cikastim in pincgavskim govedom, ki so imele poznano poreklo (Jeretina, 2004). Na osnovi popisa živali v letu 1992 in ocene stopnje ogroženosti se je začel izvajati program ohranjanja pasme. Leta 2000 je bilo cikasto govedo vključeno v program »Ohranjanje biotske raznovrstnosti v slovenski živinoreji«, na Oddelku za zootehniko, Biotehniške fakultete, Univerze v Ljubljani. Sistematično iskanje živali cikastega goveda za program ohranjanja se je pričelo leta 2002. Takrat je postala obvezna tudi identifikacija goveda z ušesnimi znamkami. Takoj je postalo jasno, da so izvorno cikasto govedo ohranili rejci na hribovskih kmetijah na Kamniškem in na območju Bohinja, kjer so se uprli prepovedi naravnega pripusta in nadaljevali z uporabo nelicenciranih cikastih bikov. Na novo je bilo registriranih okoli 300 živali cikastega goveda, ki so bile potencialno brez primesi pincgavskega goveda. Zaradi neznanih podatkov o poreklu in podobnosti v barvnem vzorcu cikastega in pincgavskega goveda, je bilo nemogoče izključiti živali s primesmi genov pincgavskega goveda v cikastem govedu. Vse živali, ki so bile po zunanjosti podobne cikastemu govedu, so bile vpisane v register in kasneje v rodovniško knjigo kot cikasto govedo. Leta 2001 so se rejci organizirali v Društvo za ohranjanje cikastega goveda v Sloveniji, ki je bilo kasneje preimenovano v Združenje rejcev avtohtonega cikastega goveda v Sloveniji.

1.1 LASTNOSTI ZUNANJOSTI

Za cikasto govedo je bil leta 2005 sprejet in potrjen rejski program (Žan in sod., 2005). Leta 2010 se je rejski program nekoliko dopolnil in ponovno sprejel (Žan Lotrič in sod., 2010). Selekcija cikastega goveda temelji na ocenjevanju lastnosti zunanjosti pri potencialnih plemenskih bikih ter pri vseh prvesnicah. Vse plemenske živali cikastega goveda, ne glede na starost, so bile prvič ocenjene v letu 2002 in 2003, ko so se ugotovile precej velike razlike v zunanjosti med živalmi znotraj populacije. Prvo ocenjevanje cikastega goveda je potekalo na način, ki je bil enoten za vse populacije v kontroli prireje mleka v Sloveniji. Leta 2006 (Žan Lotrič in sod., 2010) se je zato ponovno ocenilo vse živali v populaciji cikastega goveda z vključitvijo sklopa tako imenovanih »avtohtonih lastnosti«. Pregled je pokazal velike razlike v lastnostih zunanjosti med živalmi v populaciji cikastega goveda, zato so bile vse živali razvrščene v tri tipe in sicer: cikasti, delni cikasti in pincgavski tip.

Razvrščanje živali v ustrezen tip na podlagi ocene za avtohtonost se izvede neposredno ob koncu ocenjevanja, kar onemogoča, da bi upoštevali morebitne vplive okolja. Mednarodni komite za kontrolo proizvodnje živali (ICAR) (International agreement…, 2012) priporoča izvrednotenje ocen za lastnosti zunanjosti s statističnim modelom, kjer naj bi bili vključeni vplivi starosti, stadija laktacije in sezone. Ocenjevalci ne bi smeli delati popravkov ocen glede na starost, stadij laktacije, sezono, očeta in tehnologijo reje v času postopka ocenjevanja, ampak se ta korekcija izvede računsko s pomočjo statističnega modela.

Pri ocenjevanju cikastega goveda se zabeležijo naslednje informacije, ki bi jih lahko uporabili kot potencialne vplive »leto ocenjevanja«, »starost na dan ocenjevanja«, »število dni po telitvi« pri prvesnicah. Predpostavljamo, da sedaj prihaja do napak pri razvrstitvi živali v tip, ker se vplivov okolja ne upošteva.

Tudi pri analizah lastnosti zunanjosti za italijanske avtohtone pasme govedi valdostana (Mazza in sod., 2013), rendena (Mazza in sod., 2014) in piemontese (Mantovani in sod.,

2010) so uporabili statistični model za korekcijo vpliva starosti živali ob ocenjevanju in vpliva stadija laktacije. V model za izvrednotenje lastnosti zunanjosti pri prvesnicah asturiana de los valles govedi so prav tako vključili vplive kot so čreda, interakcija ocenjevalec-leto-sezona, čas po telitvi in starost (Gutiérrez in Goyache, 2002). Pri prvesnicah holštajn-frizijskega goveda so v model za analizo variance lastnosti zunanjosti vključili naslednje vplive: ocenjevalec, sezona telitve, starost ob telitvi ter interakcijo med čredo, sezono ocenjevanja in ocenjevalcem (Němcová in sod., 2011). Pri prvesnicah ameriškega rjavega goveda v Italiji so v model za analizo variance lastnosti zunanjosti vključili vplive kot so interakcija čreda-leto-sezona, starost ob telitvi in ocenjevalec (Samoré in sod., 2010). Nekateri avtorji (npr. Dal Zotto in sod., 2007; Klopčič in Hamoen, 2010) priporočajo tudi vključitev telesne kondicije v model kot vpliv pri analizi variance za lastnosti zunanjosti.

1.2 GENETSKA KARAKTERIZACIJA

Glede na vsa dejstva iz zgodovinskih zapisov in zaradi velikih razlik v zunanjosti med posameznimi živalmi v populaciji cikastega goveda, smo predpostavili, da se je do danes ohranilo prvotno cikasto govedo in cikasto govedo oplemenjeno s pincgavskim govedom ter prekrižano z lisastim govedom. Poleg tega imajo nekatere živali tudi v poreklu zabeležen manjši ali večji delež genotipa pincgavskega goveda, kot rezultat oplemenjevanja. Pincgavsko govedo je bilo v 70. letih prejšnjega stoletja v Avstriji pod vplivom oplemenjevanja z rdečim holštajnskim govedom (Felius, 1995), zato je prišla v populacijo cikastega goveda tudi primes rdečega holštajnskega goveda, kar je zabeleženo pri manjšem številu živali z znanim poreklom.

Med rejci, strokovno in laično javnostjo je zaradi tega še vedno prisoten dvom, katero govedo se je ohranilo, cikasto, pincgavsko ali je to samo prekrižana populacija z različnimi deleži pasem, ki so sodelovale pri nastajanju. Če se je ohranilo cikasto govedo, potem gre za avtentično pasmo, ki jo redimo samo v Sloveniji. Na drugi strani se pojavljajo predpostavke, da je to pincgavsko govedo, ki je zaradi skromnejših količin krme ostalo manjšega telesnega okvira.

Prve filogenetske raziskave sorodnosti med desetimi pasmami govedi v centralni Evropi, kamor sta bili vključeni tudi pincgavsko in pustariško govedo, so temeljile na frekvenci alel za enajst krvnih skupin in proteinskih polimorfizmov (Kidd in Pirchner, 1971). Na osnovi krvnih skupin, proteinskih polimorfizmov iz mleka in krvi so Medugorac in sod. (1994) cikasto govedo razvrstili v »Balkansko-Alpsko« skupino z nestabilno filogenetsko pozicijo. Vzorce krvi so zbirali od cikastega goveda v Zgornjem Posočju, kjer so cikasto govedo oplemenjevali z biki pincgavskega goveda z večjim deležem rdečega holštajnskega goveda, da bi povečali mlečnost. Predpostavljamo, da so bile vzorčene živali križanci treh pasem, kar bi lahko vodilo do nestabilne filogenetske pozicije.

Z razvojem molekularne genetike so raziskovalci začeli rutinsko uporabljati mikrosatelitne genetske označevalce (mikrosateliti). Medugorac in sod. (2009) so s pomočjo takšnih informacij prikazali genetsko raznolikost in sorodstvo med primitivnimi pasmami goveda na Balkanu (buša, črno anatolijsko govedo in gatačko govedo) in pasmami goveda v zahodni Evropi (tirolsko sivo, originalno rjavo, pomursko, frankovsko rumeno, lisasto, tarenteise, rdeče holštajnsko, belgijsko belo-plavo in galloway). Podobno so Edwards in sod. (2000) v Avstriji ocenili sorodstvo med pustariškim, pincgavskim, vosges ter simentalskim govedom, medtem ko so Manatrion in sod. (2008) naredili genotipizacijo dveh avstrijskih pasem govedi (koroško plavo, waldviertler blond) in madžarskim sivim govedom. Del Bo in sod. (2001) so v podobno raziskavo vključili sedem avtohtonih pasem govedi v Alpah v Italiji (črno-bela aosta, rdeče-bela aosta, kostanjeva aosta, rdeče-bela oropa, siva alpska, rendena in burlina) in izračunali genetske razdalje med njimi. V centralni Evropi so Čitek in sod. (2006) ter Czernekova in sod. (2006) proučevali genetske razdalje med češkim rdečim, nemškim rdečim, češkim lisastim, poljskim rdečim, češkim črno-belim in nemškim črno-belim govedom. Amigues in sod. (2011) so s pomočjo mikrosatelitov iskali sorodstvo med francoskimi pasmami goveda blonde d'aquitaine, limuzin in salers. Kantanen in sod. (2000) so predstavili genetsko raznolikost in strukturo populacij za 20 severno evropskih pasem govedi iz Danske, Finske, Islandije, Norveške in Švedske.

V začetnih raziskavah so bile genetske razdalje največkrat izračunane med posameznimi pasmami znotraj države ali med pasmami v sosednjih državah. Kasneje pa so raziskovalci začeli združevati podatke o pasmah iz različnih držav z namenom, da bi izračunali genetske razdalje med večino pasem govedi v Evropi in s tem pojasnili njihov izvor in razvoj (Felius in sod., 2011). Pri tem so se pojavile težave, saj so različni znanstveniki uporabljali različne mikrosatelitne genetske označevalce in je bila primerjava nemogoča ali omejena. Zato so raziskovalci v okviru organizacij FAO (Food and Agriculture Organisation of the United Nations) in ISAG (International Society of Animal Genetics) izbrali in priporočili 30 mikrosatelitnih označevalcev primernih za genotipizacijo goveda za molekularno genetske analize različnih pasem (FAO, 2011).

V zadnjem času se, namesto mikrosatelitov, čedalje bolj uveljavljajo genetski označevalci SNP (Single Nucleotide Polymorphism; polimorfizem na posameznem nukleotidu). Genotipizacija z velikim številom (cca. 54.000) označevalcev SNP (BovineSNP50 Genotyping BeadChip) je postala finančno ugodnejša in hkrati nudi večje število informacij o genomu. Žal so raziskovalci v razvoj BovineSNP50 čipa vključili predvsem spektrum alel ozko selekcioniranih, komercialnih, dobro poznanih in razširjenih pasem govedi (Matukumalli in sod., 2009). Posledično lahko na ocene genetske raznolikosti vpliva potrjena pristranost čipa, kar lahko vodi do pristranih ali celo napačnih zaključkov študij. Gautier in sod. (2010) so naredili prvo študijo na osnovi označevalcev SNP med 47 pasmami govedi iz celega sveta, ko so analizirali genetske strukture populacij ter izračunali genetske razdalje med njimi, ob tem pa niso upoštevati pristranosti in pristrano ocenili parametre genetske raznolikosti med pasmami.

V novejših molekularno genetskih študijah z vključenim velikim številom pasem govedi iz celega Sveta na osnovi genotipizacije z BovineSNP50 čipom (Decker in sod., 2009; Decker in sod., 2014) so za izračun parametrov raznolikosti zaradi pristranosti čipa namesto SNP genotipov uporabili haplotipe. Tako kot mnoge avtohtone pasme, tudi cikasto govedo ni bilo vključeno v razvoj BovineSNP50 čipa. Privatne alele značilne za avtohtone pasme govedi niso vključene v čip in tako ostanejo nezaznane. Da bi se v naši raziskavi izognili pristranim ocenam, smo uporabili haplotipe, ki smo jih sestavili iz štirih zaporednih označevalcev SNP v genomu.

Glede na veliko število raziskav, kjer so s pomočjo genetske karakterizacije ugotovili avtentičnost pasme in iz programov ohranjanja izločili živali, ki so vključevale primesi drugih pasem, smo se odločili za podoben pristop tudi pri cikastem govedu. Genotipizacija z manjšim številom mikrosatelitnih označevalcev je bila narejena na večjem številu živali, medtem ko smo kasneje ponovili genotipizacijo z večjim številom označevalcev SNP na manjšem številu živali. Na podlagi dobljenih rezultatov smo naredili genetsko karakterizacijo pasme. Cikasto govedo, kot pasma, še ni bilo razvrščeno v pasemsko skupino, zato smo jo želeli ustrezno razvrstiti.

1.3 KLAVNE LASTNOSTI IN LASTNOSTI MESA

Po drugi svetovni vojni je bilo cikasto govedo namenjeno za prirejo mleka, vendar se je načrtno rejsko delo pri pasmi zaključilo, ko so se strokovnjaki odločili pasmo pretopiti z lisastim oziroma zamenjati z rjavim govedom. Danes je mlečnost krav cikastega goveda majhna v primerjavi z drugimi pasmami, ki so usmerjene v tržno prirejo mleka. V letu 2013 je bilo na podlagi 23 laktacijskih zaključkov ugotovljeno, da so krave cikastega goveda na laktacijo priredile v povprečju 2.691 kg mleka s 3,84 % mlečne maščobe in 3,30 % mlečnih beljakovin (Sadar in sod., 2014).

Zastavilo se nam vprašanje, kako v prihodnosti ohraniti pasmo, saj je ohranjanje avtohtonih pasem bolj uspešno, če je pasma gospodarsko zanimiva in uporabna za prirejo. Zaradi majhne mlečnosti je cikasto govedo nekonkurenčno za tržno prirejo mleka, zato bi morali takšno prirejo vzdrževati s pomočjo večjih podpor. V sedanjem času bi bila pasma lahko zanimiva za »butično« prirejo mleka in predelavo le-tega v izdelke z veliko dodano vrednostjo, npr. sir, skuta, jogurt. Potrebno je poudariti, da na posameznih kmetijah, kjer se je ohranilo planšarsko gospodarstvo, pasmo še vedno uporabljajo v ta namen.

S podobnim problemom se srečujejo tudi rejci drugih avtohtonih pasem govedi. Francoski kombinirani pasmi goveda salers in aubrac so v preteklosti uporabljali za delo in za prirejo mleka. Danes večino krav obeh pasem redijo kot krave dojilje za prirejo čistopasemskih ali križanih telet z mesnimi pasmami za nadaljnje pitanje (Piedrafita in sod., 2003). Prireja mleka s kravami salers goveda se je ohranila le v manjšem številu rej, ki so našli tržno nišo v »butični« prodaji mlečnih izdelkov. Večina avtohtonih pasem govedi iz alpskega prostora je bila v preteklosti kombiniranih s poudarkom na prireji mleka. Danes pa je v primerjavi s pasmami za tržno prirejo mleka njihova mlečnost majhna. Raziskovalci so se zato odločili proučiti možnosti prireje mesa z avtohtonimi pasmami in določiti klavno kakovost mesa teh pasem. Nekateri so proučevali prirejo mesa v tipičnih proizvodnih sistemih s kravami dojiljami lokalnih pasem v pašni reji (Piedrafita in sod., 2003; Serra in sod., 2004), drugi pa so intenzivno pitali bike lokalnih pasem z namenom proučitve njihove zmogljivosti za prirejo mesa (Cozzi in sod., 2009; Özlütürk in sod., 2004).

V rejskem programu za cikasto govedo je sicer zapisano, da je cikasto govedo kombinirana pasma s poudarkom na prireji mleka (Žan Lotrič in sod., 2010). Kljub temu pa sedaj večina rejcev cikastega goveda redi krave dojilje, kjer je glavni dohodek odstavljeno tele ob koncu laktacije.

V preteklosti je bil glavni namen reje cikastega goveda prireja mleka in predelava le tega v sir, zato se klavnim lastnostim in lastnostim mesa ni posvečalo pozornosti. Kljub temu smo zasledili zapis (Povše, 1894), da je bilo meso tolminskega goveda zelo cenjeno pri mesarjih v Trstu in Gorici. Meso telet tolminskega goveda je bilo poznano po fini strukturi vlaken in izjemnem okusu, zaradi česar so mesarji plačevali po šest kron več za kilogram takega mesa v primerjavi z mesom drugih pasem. Naj spomnimo, da je bilo tolminsko govedo lokalna populacija goveda oplemenjena z belanskim govedom.

Vprašali smo se, ali je morda cikasto govedo v sedanjih razmerah in času primerno tudi za prirejo mesa. Glavni namen naših prvih raziskav na področju mesa cikastega goveda je bil dobiti vpogled v klavno kakovost cikastega goveda, kakor je bila ovrednotena na klavni liniji v komercialnih klavnicah v Sloveniji. Zbrali smo podatke iz klavnic od leta 2005 do 2007. Cikasto govedo je v letu 2007 predstavljalo le 0,24 % vsega zaklanega goveda v Sloveniji, ki je bilo po posameznih kategorijah zelo raznoliko v masi klavnega trupa. Povprečna masa klavnega trupa mladih bikov do starosti 24 mesecev je bila 260,3 ± 73,2 kg. Mladi biki v kategoriji A (do starosti 24 mesecev) so bili zaklani pri povprečni starosti 18,6 ± 4,7 mesecev. Večina jih je bila razvrščena po EUROP klasifikaciji v O razred za mesnatost in v razred 2 za zamaščenost (Simčič in sod., 2008). Zaradi majhnega števila zaklanih živali (645) vseh kategorij, nepozanega izvora (velikega števila kmetij z različnim tradicionalnim načinom reje) in neznanega morebitnega deleža primesi drugih pasem pri zaklanih živalih, je bilo težko zaključiti, kaj je vzrok za slabšo klavno kakovost cikastega goveda v primerjavi z drugimi pasmami. Tudi sicer med odkupovalci živine in mesarji velja splošno uveljavljeno mnenje, da je cikasto govedo popolnoma neprimerno za prirejo mesa, zato rejcem za te živali plačujejo manj.

Podobno raziskavo smo ponovili še v letu 2011 (Simčič in sod., 2011a) z nekoliko večjim številom zaklanih živali cikastega goveda v komercialnih klavnicah od leta 2007 do 2010. Klavne lastnosti cikastega goveda smo takrat primerjali z rjavim govedom. Cikasti biki mlajši od 24 mesecev (n = 391) so dosegli manjšo maso klavnega trupa (266,7 ± 3,3 kg) v primerjavi mladimi rjavimi biki (330,0 ± 0,6 kg). Ocenjena mesnatost (EUROP klasifikacija; 1 - 15) je bila v povprečju zelo podobna pri mladih bikih cikastega (6,4) in rjavega goveda (6,3). Poleg tega so bili cikasti biki v kategoriji A značilno manj zamaščeni (5,8) od rjavih bikov (6,4). Zaključili smo, da je cikasto govedo manjšega telesnega okvira, kar se je izrazilo tudi z manjšo maso klavnih trupov. Presenetljiva pa je bila ugotovitev, da so bili cikasti biki starejši od 24 mesecev (B kategorija) bolj mesnati in manj zamaščeni od rjavih bikov, kar je potrjevalo domnevo, da se cikaste bike oddaja v zakol premlade in nedopitane.

Populacija cikastega goveda se je zadnja leta povečevala, zato je bilo na voljo vse več odstavljenih bikcev, ob koncu pašne sezone, primernih za nadaljnje pitanje. To je vodilo k odločitvi, da smo od rejcev začeli odkupovati odstavljene bikce cikastega goveda vsako leto po koncu pašne sezone, več let zapored. Odstavljene bikce približno enake telesne mase in starosti smo vsako leto v jeseni uhlevili na Pedagoško raziskovalni center (PRC) Logatec in izvedli več poskusov pitanja. Tako smo lahko izključili vplive okolja (tehnologija reje, krmni obrok) saj so bili vsi biki rejeni v enakih pogojih reje. Namen teh poskusov je bil proučiti sposobnost bikov cikastega goveda za rast v intenzivnih in v ekstenzivnih pogojih reje ter ugotoviti klavno kakovost in kakovost mesa. V tehnologijo pitanja smo vključili tudi pitanje na paši v času druge pašne sezone.

1.4 HIPOTEZE

V disertaciji smo uporabili večje število različnih zbirk podatkov in z njimi preverili naslednje hipoteze:

- Na lastnosti zunanjosti in posledično na razvrstitev živali v ustrezen tip vplivajo poleg genetskih dejavnikov tudi dejavniki okolja.
- Cikasto govedo je avtentična avtohtona pasma, ki je genetsko različna od pincgavskega goveda in od drugih pasem govedi v Alpah.
- Biki cikastega goveda so ob ustrezni tehnologiji pitanja primerni za prirejo mesa in imajo primerljivo klavno kakovost in kakovost mesa s kombiniranimi pasmami govedi.

2 ZNANSTVENA DELA

2.1 ANALIZA LASTNOSTI ZUNANJOSTI IN OCENA GENETSKIH PARAMETROV PRI CIKASTEM GOVEDU

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Neobjavljeno delo

IZVLEČEK

Cilj raziskave je bila analiza lastnosti zunanjosti pri 330 plemenskih bikih in 1.086 prvesnicah cikastega goveda. Sistem ocenjevanja zunanjosti pri cikastem govedu vključuje merjene, posamezne ocenjevane in sestavljene ocenjevane lastnosti. Posamezne ocenjevane lastnosti so razdeljene v tri sklope in sicer, avtohtonost, telesne oblike in pri prvesnicah še vime. Pri potencialnih plemenskih bikih se oceni tri sestavljene ocenjevane lastnosti (avtohtonost, omišičenost, telesne oblike), pri prvesnicah se poleg teh oceni še vime. Sistematski del modela smo analizirali s proceduro GLM v programskem paketu SAS, ki je vključeval vplive leto ocenjevanja in starost živali ob ocenjevanju kot linearno regresijo. Sistematski del modela za prvesnice je poleg teh dveh vplivov vključeval še čas po telitvi kot linearno regresijo. Pri prvesnicah smo z modelom živali ocenili tudi parametre disperzije za vse lastnosti zunanjosti z metodo REML v paketu VCE-6. Model živali je poleg sistematskih vplivov vključeval še naključni vpliv črede in aditivni genetski vpliv živali. V povprečju so bili 14,6 mesecev stari plemenski biki v vihru visoki 117,1 cm, prvesnice pa 126,5 cm pri starosti 33,9 mesecev. Na podlagi višine vihra in posameznih ocenjevanih lastnosti iz sklopa avtohtonost so bili potencialni plemenski biki in prvesnice razvrščeni v cikasti, delni cikasti in pincgavski tip. Ocenjeni dednostni deleži za merjene lastnosti so bili od 0,48 do 0,79 in za posamezne ocenjevane lastnosti v sklopih pa od 0,37 do 0,87 za avtohtonost, od 0,17 do 0,70 za telesne oblike in od 0,26 do 0,51 za vime. Ocenjeni dednostni deleži za sestavljene lastnosti za avtohtonost, omišičenost, telesne oblike in vime so bili 0,62, 0,29, 0,20 in 0,30. Ocenjeni deleži pojasnjene variance z vplivom črede so bili od 0,08 do 0,25 za merjene lastnosti in za posamezne ocenjevane lastnosti v sklopih od 0,01 do 0,08 za avtohtonost, od 0,01 do 0,20 za telesne oblike in od 0,06 do 0,15 za vime. Ocenjeni deleži pojasnjene variance z vplivom črede za sestavljene lastnosti avtohtonost, omišičenost, telesne oblike in vime so bili 0,10, 0,27, 0,09 in 0,13. Ocenjeni dednostni deleži za lastnosti zunanjosti cikastega goveda so primerljivi z ocenjenimi dednostnimi deleži pri drugih pasmah in omogočajo genetsko vrednotenje cikastega goveda. Na osnovi napovedanih plemenskih vrednosti je mogoče vsako ocenjeno žival ustrezneje razvrstiti v posamezen tip. Vse navedeno lahko uporabimo za učinkovitejšo selekcijo v populaciji še posebno z vidika ohranjanja avtohtonih lastnosti.

Ključne besede: cikasto govedo, lastnosti zunanjosti, ocenjevanje, dednostni delež, genetske korelacije

UVOD

Cikasto govedo je slovenska avtohtona kombinirana pasma s poudarkom na prireji mleka. Rejski cilj je ohranjanje pasme v prvotnem tipu in preprečevanje parjenja v sorodstvu. Cikasto govedo je razširjeno skoraj po vsej Sloveniji, vendar je številčno najbolj zastopano na območju, od koder izvira (Bohinj, okolica Kamnika in okolica Kobarida). Barvni vzorec je tipičen in značilen za to pasmo ter se zelo razlikuje od drugih pasem govedi v Sloveniji. Nekatere živali cikastega goveda so po barvnem vzorcu bolj podobne pincgavskemu govedu, druge pa tux-zillertaler govedu iz Avstrije (Sambraus, 1999). Osnovna barva plašča je rumenordeča do temno rdečerjava, največkrat kostanjevo rjava, ki mora prevladovati nad belo barvo. Glava mora biti osnovne barve. Po hrbtu imajo živali širši ali ožji bel pas, ki se nadaljuje pod repom do vimena ali mod in po trebuhu naprej do prsi. Rep je bele barve. Ožji ali širši beli pasovi so prisotni tudi čez zgornji del prednjih nog (v predelu komolčnega sklepa) in zadnjih nog (v predelu kolenskega sklepa). Barva vseh sluznic je rožnata. Barva rogov ob korenu je belorumena, na gornji tretjini rjavkasta, konice pa so svetlejše. Parklji so temne barve (Navodila za presojo …, 1935; Žan Lotrič in sod., 2010). Zunanji znak pasemske pripadnosti je bela ožja ali širša podolžna lisa po hrbtu in trebuhu (Navodila za presojo …, 1935).

Značilnost pasme je sposobnost za pašo na visokogorskih pašnikih. Velikost telesnega okvira je majhna do srednja. Živali so dobro plodne in dolgožive, kar je skupna lastnost skoraj vsem avtohtonim pasmam na alpskem območju. V letu 2013 je bilo na podlagi 23 laktacijskih zaključkov ugotovljeno, da so krave cikastega goveda v standardni laktaciji priredile v povprečju 2.691 kg mleka s 3,84 % mlečne maščobe in 3,30 % mlečnih beljakovin (Sadar in sod., 2014). Kljub poudarku na prireji mleka, večina rejcev cikastega goveda redi krave dojilje. Rejci oddajajo v zakol mlajša (kategorija V) in starejša teleta (kategorija Z) ob povprečni starosti 4,8 oziroma 9,7 mesecev. Klavni trupi pri mlajših teletih tehtajo v povprečju 94,4 kg, pri starejših pa 136,7 kg. Mladi biki se oddajo v zakol pri povprečni starosti 19,9 mesecev in klavni trupi so v povprečju težki 266,7 kg (Simčič in sod., 2011). Mladi biki vključeni v poskusno pitanje na Pedagoško raziskovalnem centru (PRC) Logatec so dosegli v povprečju 595,8 kg telesne mase ob zakolu, 332,7 kg mase klavnih trupov in 55,8 % klavnost pri povprečni starosti 22,5 mesecev (Žgur in sod., 2014).

Selekcija cikastega goveda temelji na lastnostih zunanjosti, ki so bile pri živalih prvič ocenjene v letih 2002 in 2003, ko je bila ugotovljena velika fenotipska raznolikost med živalmi znotraj populacije. Poleg tega je prvo ocenjevanje cikastega goveda potekalo po sistemu ocenjevanja, ki je bil takrat v uporabi za tri pasme govedi (rjavo, lisasto, črno-belo), ki so jih redili za prirejo mleka v Sloveniji (Pogačar in sod., 1995; Pogačar in Potočnik, 1997). Na podlagi ugotovljene večje raznolikosti med živalmi so v letu 2006 vse plemenske živali ocenili še enkrat. Ocenjevanje je takrat potekalo na podlagi obrazca, ki je bil posebej prirejen za cikasto govedo.

Za potrebe selekcije se ocenjujejo potencialni plemenski biki in vse prvesnice. Za cikasto govedo je bil leta 2005 sprejet in potrjen rejski program (Žan in sod., 2005). Leta 2010 se je rejski program nekoliko dopolnil in ponovno sprejel (Žan Lotrič in sod., 2010). V okviru tega se izvaja ocenjevanje zunanjosti, ki vključuje merjene in ocenjevane lastnosti. Pri bikih je merjenih lastnosti sedem, pri prvesnicah pa štiri. S pomočjo merilnega traku se pri plemenskih bikih določi tudi telesna masa na podlagi obsega prsi. Posebnost ocenjevanja v primerjavi z drugimi pasmami je dvanajst tako imenovanih posameznih lastnosti za avtohtonost, ki opisujejo pasemske značilnosti. Poleg tega se oceni tudi šest posameznih lastnosti za telesne oblike in pri prvesnicah še pet posameznih lastnosti za vime. Na koncu se oceni še štiri sestavljene lastnosti. Na obrazcu za ocenjevanje zunanjosti sta tudi dve lastnosti (temperament in iztok mleka), ki nista lastnosti zunanjosti in sta ocenjeni na podlagi izjave rejca z ocenami od 1 do 5. Na podlagi posameznih ocen za avtohtonost, ocene za izraženost skočnega sklepa in višine vihra se vse živali neposredno na koncu ocenjevanja razvrsti v tri tipe (cikasti, delni cikasti, pincgavski). Na podlagi ocen zunanjosti se odberejo potencialni plemenski biki in bikovske matere.

Rejski program (Žan Lotrič in sod., 2010) določa, da se v ocenjevanje zunanjosti vključi vse prvesnice in krave, ki niso bile ocenjene kot prvesnice. Starost prvesnice na dan ocenjevanja je omejena na najmanj 560 dni tako, da se iz ocenjevanja po prvi telitvi izloči vse prvesnice, ki so telile premlade (t.i. »prezgodnjice«). Prvesnice, ki so telile mlajše od 560 dni, se oceni po drugi zaporedni telitvi. Največja starost prvesnice oz. krave na dan ocenjevanja ni omejena, ker se po rejskem programu predvideva, da se ocenijo tudi vse krave, ki kot prvesnice iz različnih razlogov niso bile ocenjene. Čas ocenjevanja je prilagojen tehnologiji reje, zato se živali ocenjuje izven pašne sezone. Po rejskem programu je predvideno ocenjevanje prvesnic od 15 do 120 dne po telitvi, kar velikokrat ni mogoče zaradi paše. Posebnost sistema ocenjevanja cikastega goveda je tudi, da so v ocenjevanje lastnosti zunanjosti vključeni tudi vsi potencialni plemenski biki, ki se jih oceni v starosti od 12 do 20 mesecev. Velikost populacije cikastega goveda je, v primerjavi z ostalimi pasmami v Sloveniji, majhna, zato vse plemenske živali ocenjuje samo en ocenjevalec. Analiza lastnosti zunanjosti se opravlja z namenom spremljanja primernosti porazdelitve ocen posameznih lastnostih in je hkrati osnova za oceno genetskih parametrov, ki so potrebni za napovedovanje plemenskih vrednosti.

Genetske parametre za lastnosti zunanjosti pri specializiranih mlečnih pasmah govedi so že v preteklosti ocenili pri prvesnicah holštajn-frizijskega goveda (Van Dorp in sod., 1998; Rupp in Boichard, 1999; Larroque in Ducrocq, 2001; Neuenschwander in sod., 2005; de Haas in sod., 2007; Nemcova in sod., 2011), jersey goveda (Thomas in sod., 1985; Norman in sod., 1988; Rogers in sod., 1991), rjavega goveda (Norman in sod., 1988; Dal Zotto in sod., 2007; de Haas in sod., 2007; Samore in sod.; 2010), rdečega holštajnskega goveda (de Haas in sod., 2007) ter pri prvesnicah ayrshire, guernsey in shorthorn goveda (Norman in sod., 1988). Raziskovalci so največkrat iskali povezave med lastnostmi zunanjosti in mlečnostjo, plodnostjo ter dolgoživostjo živali. Analizo lastnosti zunanjosti in ocene genetskih parametrov za pasme govedi za prirejo mleka v Sloveniji so predstavili Potočnik (2005) in Logar in sod. (2011) za črno-belo, rjavo in lisasto govedo ter Špehar in sod. (2012) za rjavo govedo.

Pri specializiranih mesnih pasmah govedi so genetske parametre za lastnosti zunanjosti pri prvesnicah proučevali Gengler in sod. (1995) pri belgijskem belo-plavem govedu z dvojno omišičenostjo in Guitiérrez in Goyache (2002) ter Guitiérrez in sod. (2002) pri španskem asturiana de los valles govedu. S pomočjo ocen zunanjosti, ki so v korelaciji z dolgoživostjo, so lahko dolgoživost tudi posredno ocenili (Forabosco in sod., 2004). V zadnjem obdobju so bile objavljene analize lastnosti zunanjosti tudi pri prvesnicah nekaterih avtohtonih pasem govedi. Genetske parametre za lastnosti zunanjosti pri prvesnicah italijanskih avtohtonih pasem so ocenili pri chianina (Forabosco in sod., 2004), piemontese (Mantovani in sod., 2010), rendena (Mazza in Mantovani, 2012; Mazza in sod., 2014), cabanina (Comunod in sod., 2013) in valdostana govedu (Mazza in sod., 2013). Kastelic in sod. (2005) so analizirali merjene lastnosti zunanjosti pri prvesnicah cikastega goveda na podlagi prvotnega enotnega sistema ocenjevanja zunanjosti in potrdili raznolikost med živalmi znotraj populacije.

Lastnosti zunanjosti pri cikastem govedu se na poseben način ocenjujejo od leta 2006 dalje. Namen te raziskave je bil analizirati lastnosti zunanjosti in oceniti genetske parametre za merjene in ocenjevane lastnosti ter s tem pripraviti osnovo za pravilnejšo razvrstitev živali v tipe ter preveriti smiselnost uvedbe rutinskega napovedovanja plemenskih vrednosti za potrebe selekcije.

MATERIAL

Podatki

Podatke smo pridobili iz Centralne podatkovne zbirke (CPZ) Govedo, ki jo vodijo na Kmetijskem inštitutu Slovenije (KIS), ki je druga priznana organizacija v živinoreji, med drugim pooblaščena tudi za arhiviranje podatkov. Pridobljeni podatki zabeleženi v okviru ocenjevanja lastnosti zunanjosti so vključevali 2.397 živali cikaste pasme, od katerih je bilo 375 plemenskih bikov in 2.019 živali ženskega spola (prvesnice in krave) ocenjenih v letih od 2002 do 2014. Največ živali je bilo ocenjenih v letu 2006, ko je bil vpeljan nov način ocenjevanja, skladen z rejskim programom za cikasto govedo (Žan in sod., 2005). V letu 2006 se je ponovno ocenila celotna populacija plemenskih živali cikaste pasme, tudi tistih, ki so bile pred letom 2006 že ocenjene na enoten način, ki je veljal za populacije prvesnic vključenih v kontrolo prireje mleka v Sloveniji.

Izbor podatkov

V nadaljnjo analizo smo vključili samo živali, ki so bile ocenjene po novem načinu ocenjevanja. Živali, ki so bile ocenjene pred letom 2006 smo iz obdelave izključili in s tem izključili tudi sistematski vpliv različnega načina ocenjevanja. V skladu z omejitvami v rejskem programu, glede ustrezne starosti na dan ocenjevanja, bi v analizo vključili zelo majhno število plemenskih bikov, saj se v praksi biki ocenjujejo mlajši kot je priporočeno. Da bi dosegli boljšo ocenljivost posameznih vplivov smo v analizo vključili vse plemenske bike, ki so bili na dan ocenjevanja stari od 10 do 20 mesecev. Pri upoštevanju omejitev po rejskem programu za prvesnice glede na ustrezno starost na dan ocenjevanja, bi v obdelavo zajeli 2.019 ženskih živali, kamor bi bile vključene tudi krave, saj po rejskem programu največja starost ob ocenjevanju ni omejena. Predpostavili smo, da je ocenjevanje zunanjosti namenjeno prvesnicam, zato smo omejili starost ob ocenjevanju na največ 1.460 dni oziroma 4 leta, tako kot so priporočali de Haas in sod. (2007). Poleg tega smo izključili tudi vse krave mlajše od štirih let, ki so bile ocenjene šele po drugi zaporedni telitvi. V to skupino so spadale prvesnice, ki so telile mlajše od 560 dni in krave, ki so bile iz različnih razlogov ocenjene šele po drugi telitvi. Prvesnic, ki so bile na dan ocenjevanja izven priporočenega stadija v laktaciji, nismo izključili iz nadaljnje analize. Vsem navedenim kontrolam je ustrezalo 1.086 prvesnic in 330 plemenskih bikov cikastega goveda, ki smo jih vključili v končno analizo (Preglednica 1). Živali so bile ocenjene v letih od 2006 do 2014 (Preglednica 2).

Preglednica 1: Število živali cikastega goveda vključenih v analizo lastnosti zunanjosti

	n	Starost (dni)			Število dni po telitvi (dni)		
		Povprečje ± SD	Min	Max	Povprečje ± SD	Min	Max
Plemenski biki	330	446,2 ± 81,3	307	850			
Prvesnice	1086	1033,0 ± 161,2	628	1460	230,0 ± 109,6	2	446

n – število živali, SD – standardni odklon, Min – najmanjša vrednost, Max – največja vrednost

Preglednica 2: Porazdelitev ocenjenih plemenskih bikov in prvesnic cikastega goveda po letih

Leto	Plemenski biki	Prvesnice	Skupaj
2006	25	99	124
2007	26	101	127
2008	30	146	176
2009	35	137	172
2010	35	153	188
2011	40	154	194
2012	46	177	223
2013	53	119	172
2014	40	0	40
Skupaj	330	1086	1416

Sistem ocenjevanja zunanjosti vključuje sklop merjenih lastnosti (♂- 7, ♀ - 4), sklop posameznih ocenjevanih lastnosti za avtohtonost (12), sklop posameznih ocenjevanih lastnosti za telesne oblike (6), sklop posameznih ocenjevanih lastnosti vimena (4) in sklop sestavljenih lastnosti (♂ - 3, ♀ - 4). Istočasno se na podlagi izjave rejca ocenjuje še temperament in iztok mleka. Poleg tega se zabeležijo še odstopanja od želenih lastnosti zunanjosti kot napake. Ocenjevane napake v sklopu za avtohtonost so: temen gobec, neustrezna barva plašča, beli znaki na glavi, beli znaki na nogah, pikasto pisana barva plašča, prekinjena hrbtna lisa in hrbtna lisa na križu. Ocenjevane napake v sklopu za telesne oblike so: razplečenost, visoko nasajen rep, vdolbina med sednicama, kravja stoja in razprti parklji. Ocenjevane napake v sklopu za vime so: stopničasto vime, lijakasti seski in stran štrleči seski. Sestavljene lastnosti ocenjujejo avtohtonost (pasemske značilnosti), omišičenost, telesne oblike in vime. Merjene lastnosti so podane v centimetrih, ocenjevane pa na linearni lestvici z ocenami od 1 do 9.

Merjene lastnosti za velikost okvirja, ki se merijo z Lydtinovo palico so pri plemenskih bikih in prvesnicah višina vihra, višina križa in dolžina telesa. Pri plemenskih bikih se izmerijo še širina prsi, globina prsi in širina križa. Z merilnim trakom se pri plemenskih bikih in prvesnicah izmeri obseg prsi, na podlagi katerega se s pomočjo lestvice na merilnem traku določi telesna masa (kg) samo pri plemenskih bikih. Enota merjenja za vse merjene lastnosti je centimeter (cm).

Posamezne lastnosti za avtohtonost, ki so pasemske značilnosti, se ocenjujejo pri plemenskih bikih in prvesnicah z ocenami 1 do 9. Ocena 1 pomeni nezaželeno oceno za lastnost, ocena 5 povprečno in ocena 9 zelo zaželeno oceno. Ocena 1 ne pomeni pri vseh lastnosti najmanj izražene lastnosti, kakor tudi ne pomeni ocena 9 najbolj izražene lastnosti, kot je poznano pri linearnem načinu ocenjevanja zunanjosti v skladu s pravili Mednarodnega komiteja za kontrolo proizvodnje živali - ICAR (International agreement…, 2012; Klopčič in Hamoen, 2010). V preglednicah 4 in 5 je za vsako posamezno lastnost za avtohtonost navedeno, kaj pomenita ekstremni oceni 1 in 9. Ob ocenjevanju lastnosti za avtohtonost se zabeležijo tudi napake zunanjosti glede barve plašča in sluznic. Posamezne lastnosti za telesne oblike pri plemenskih bikih in prvesnicah ter posamezne lastnosti za vime se pri prvesnicah ocenjujejo z ocenami od 1 do 9 v skladu s pravili ICAR (International agreement…, 2012).

Sestavljena ocena za avtohtonost se oceni z upoštevanjem optimalnih vrednosti nekaterih posameznih lastnosti za avtohtonost, za izraženost skočnega sklepa ter za višino vihra (Preglednica 3), kot je navedeno v rejskem programu (Žan Lotrič in sod., 2010).

Preglednica 3: Optimalne ocene za lastnosti, ki se upoštevajo v sestavljeni lastnosti za avtohtonost

Sklop	Lastnost	Optimalna vrednost
Lastnosti za avtohtonost	Dolžina glave	6 – 8
	Izraženost oči	6 – 8
	Debelina rogov	6 – 8
	Dolžina rogov	6 – 9
	Usmerjenost rogov	6 – 9
	Vrat	7 – 9
	Izraženost podgrline	6 – 9
Lastnosti za telesne oblike	Izraženost skočnega sklepa	6 – 9
Merjene lastnosti telesnega okvira	Višina vihra ♀	≤ 125 cm
	Višina vihra ♂	≤ 115 cm

Sestavljeno oceno za omišičenost predstavlja predvsem ocena zunanje linije stegna pri pogledu od zadaj z ocenami 1 - 9. Sestavljena ocena za telesne oblike (1 – 9) se oceni na podlagi posameznih lastnosti za telesne oblike in z upoštevanjem napak zabeleženih v tem sklopu. Sestavljena ocena za vime (1 - 9) se oceni na podlagi posameznih lastnosti za vime in z upoštevanjem napak zabeleženih v tem sklopu.

Glede na priporočila ICAR-ja (International agreement…, 2012) naj bi bila izračunana srednja vrednost in standardni odklon analizirana z namenom spremljanja dela ocenjevalcev. Srednja vrednost naj bi bila okoli 5, kar se izračuna kot razlika med največjo in najmanjšo možno oceno deljeno z 2. Standardni odklon naj bi bil okoli 1,5, kar izračunamo kot razliko med največjo in najmanjšo oceno kateri prištejemo 1 in delimo s 6.

Vse prvesnice (1.086) z ocenjenimi lastnostmi zunanjosti in njihovi znani predniki so bili vključeni v matriko sorodstva (skupaj 1.747 živali). Očetje so bili poznani pri 87,8 % prvesnic, matere pa pri 81,3 % prvesnic. Prvesnic, ki so imele poznane očete in matere je bilo 77,3 %. Vseh 1.086 prvesnic je bilo potomk 180 znanih očetov in 793 znanih mater.

METODE

Sistematski del statističnega modela smo analizirali s proceduro GLM v statističnem paketu SAS/STAT (SAS Institute Inc., 2001). Model 1 smo uporabili za lastnosti zunanjosti pri plemenskih bikih, model 2 za lastnosti zunanjosti pri prvesnicah:

$$y_{ijk} = \mu + L_i + b_I(x_{ijk} - \bar{x}) + e_{ijk} \qquad \text{Model 1}$$

$$y_{ijk} = \mu + L_i + b_I(x_{ijk} - \bar{x}) + b_{II}(z_{ijk} - \bar{z}) + e_{ijk} \qquad \text{Model 2}$$

kjer je y_{ijk} lastnost zunanjosti, μ je povprečje populacije, L_i je sistematski vpliv leta ocenjevanja (i = 1,…, 9), b_I je linearni regresijski koeficient za starost na dan ocenjevanja, x_{ijk} je starost na dan ocenjevanja (dnevi), b_{II} je linearni regresijski koeficient za čas po telitvi, z_{ijk} je čas po telitvi na dan ocenjevanja (dnevi) in e_{ijk} je naključni ostanek.

Za oceno parametrov disperzije pri prvesnicah (Model 3) smo sistematskemu delu modela 2 dodali še naključna vpliva čreda (h_j) in žival kot aditivni genetski vpliv (a_{ijk}).

$$y_{ijk} = \mu + L_i + b_I(x_{ijk} - \bar{x}) + b_{II}(z_{ijk} - \bar{z}) + h_j + a_{ijk} + e_{ijk} \qquad \text{Model 3}$$

Komponente variance in kovarianc za direktni aditivni genetski vpliv (vpliv živali), vpliv črede in ostanek smo ocenili z modelom živali z metodo REML v paketu VCE-6 (Groeneveld in sod., 2010). V matrični enačbi smo uporabljeni model zapisali kot:

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{Zu} + \boldsymbol{e}$$

kjer je $\boldsymbol{y}$ vektor meritev ali ocen za vse lastnosti zunanjosti, $\boldsymbol{X}$ je matrika dogodkov za sistematske vplive, $\boldsymbol{Z}$ je matrika dogodkov za naključne vplive, $\boldsymbol{\beta}$ je vektor parametrov za sistematske vplive, $\boldsymbol{u}$ je vektor naključnih vplivov in $\boldsymbol{e}$ je vektor ostanka.

Parametre disperzije smo za biološko podobne lastnosti ocenjevali z več-lastnostnimi mešanimi modeli, za vsako skupino lastnosti posebej. Vse lastnosti smo razdelili v šest skupin. Sklop merjenih lastnosti je bil vključen v skupino 1 (višina vihra, višina križa, dolžina telesa, obseg prsi). Sklop avtohtonih lastnosti smo razdelili na tri skupine. Lastnosti glave (dolžina glave, plemenitost glave, izraženost oči, debelina rogov, dolžina rogov, usmerjenost rogov) so bile v skupini 2. Lastnosti vratu (vrat, izraženost podgrline) sta bili v skupini 3 in lastnosti barve plašča (barva plašča, izraženost hrbtne lise, izraženost pasov na zadnjih nogah, izraženost pasov na prednjih nogah) v skupini 4. Sklop lastnosti za telesne oblike (hrbet, nagib križa, kot skočnega sklepa, izraženost skočnega sklepa, biclji, parklji, telesne oblike – sestavljena lastnost) je bil v skupini 5. Sklop lastnosti za vime (vime pod trebuhom, globina vimena, debelina prednjih seskov, dolžina prednjih seskov, vime – sestavljena lastnost) je bil v skupini 6. Dve sestavljeni lastnosti (avtohtonost, omišičenost) smo analizirali z eno-lastnostnim mešanim modelom.

REZULTATI IN RAZPRAVA

Pričujoča raziskava je prva podrobna analiza lastnosti zunanjosti plemenskih živali v populaciji cikastega goveda. Glede na posebnost sistema ocenjevanja je bil le-ta nekoliko bolj podrobno opisan. Ocenjevanje lastnosti zunanjosti skladno z Rejskim programom (Žan Lotrič in sod., 2010) vključuje merjene in ocenjevane lastnosti zunanjosti pri plemenskih bikih in prvesnicah, ki se nekoliko razlikujejo med spoloma. Ocenjevanje zunanjosti v skladu z Rejskim programom, ki velja od leta 2010 dalje (Žan Lotrič in sod., 2010) je vključevalo dve lastnosti več (plemenitost glave, dolžina rogov) v primerjavi z Rejskim programom iz leta 2005 (Žan in sod., 2005).

Za analizo variance lastnosti zunanjosti živali nismo razvrstili glede na tip, temveč smo zajeli celotno populacijo, ne glede na tip. Analizo variance smo naredili ločeno po spolu zaradi razlike v povprečni starosti med spoloma in različnih dejavnikov, ki so vplivali na lastnosti zunanjosti glede na spol.

Cikasto govedo je zgodaj zrela pasma, zato so telice sposobne za oploditev že zelo zgodaj, pri starosti 10 mesecev ali celo manj. Do prezgodnjih oploditev in posledično do prezgodnjih telitev pride največkrat na kmetijah, kjer imajo v čredi na paši plemenskega bika za naravni pripust. V takih primerih je v rejskem programu določeno, da se prvesnice, ki so telile mlajše od 560 dni oceni šele po drugi telitvi. Podobno kot pri cikah se z zgodnjimi telitvami srečujejo tudi pri drugih pasmah (de Haas in sod., 2007), vendar ocenijo tudi take prvesnice po prvi telitvi. Na ta način izključimo sistematski vpliv zaporedne telitve na lastnosti zunanjosti do česar prihaja pri cikah po sedaj veljavnih priporočilih.

V Švici (de Haas in sod., 2007) prvesnice holštajnskega, ameriškega rjavega in rdečega holštajnskega goveda telijo pri starosti od 500 do 1.460 dni in jih ocenijo pri starosti od 500 do 1.825 dni. Za primerjavo lahko navedemo, da se prvesnice rjavega goveda v Sloveniji ocenjuje pri starosti od 505 do 1.565 dni (Špehar in sod., 2012), prvesnice češkega holštajnskega goveda pri starosti 660 do 960 dni (Němcová in sod., 2011) in prvesnice piemontese goveda pri starosti 670 do 1.160 dni (Mantovani in sod., 2010). Pri chianina govedu v Italiji pa so v ocenjevanje zunanjosti vključene tako prvesnice kot tudi krave po drugi zaporedni telitvi in vpliva zaporedne telitve ne upoštevajo (Forabosco in sod., 2004).

Za prvesnice cikastega goveda je v rejskem programu določeno, da se jih oceni 15. do 120. dan po telitvi, kar je v skladu z Navodili ICAR (International agreement…, 2012), ki tudi priporoča, da se presušenih krav ne bi vključilo v ocenjevanje. Čas štirih mesecev po telitvi je zelo kratek, zato npr. prvesnice češkega holštajnskega goveda ocenjujejo med 30 in 210 dnem po telitvi (Němcová in sod., 2011). Vse plemenske živali cikastega goveda v Sloveniji ocenjuje samo en ocenjevalec, saj ICAR priporoča, da naj bi vsak ocenjevalec v enem letu ocenil vsaj 200 živali določene pasme. Poleg tega isti ocenjevalec ocenjuje tudi prvesnice drugih pasem.

Opisna statistika

Opisna statistika je prikazana posebej za plemenske bike (preglednica 4) in prvesnice (preglednica 5) skupaj z opisi lastnosti. Plemenski biki cikaste pasme (preglednica 4) so bili v povprečju v vihru visoki 117,09 ± 4,63 cm in nekoliko nadgrajeni, saj so bili v križu v povprečju visoki 120,20 ± 4,71 cm, kar je pričakovano glede na starost. Povprečna dolžina telesa je bila 116,15 ± 6,71 cm, kar kaže na kvadraten telesni okvir. Povprečna telesna masa je bila 319,42 ± 61,57 kg z največjim koeficentom variabilnosti (19,28 %) med vsemi merjenimi lastnostmi. Sestavljene lastnosti so bile v povprečju za avtohtonost 6,36 ± 1,18, za omišičenost 5,73 ± 1,13 in za telesne oblike 6,38 ± 1,01. Koeficient variabilnosti je bil pri plemenskih bikih za merjene lastnosti od 5,78 % do 19,28 %. Pri analiziranju ocen smo opazili tudi zelo majhno zastopanost obeh ekstremnih ocen na lestvici, kar potrjujejo tudi majhni standardni odkloni pri nekaterih lastnostih. Nekatere lastnosti niso bile ocenjene z ekstremnima ocenama, čeprav bi lestvica morala pokriti biološke ekstreme populacije, ki se ocenjuje (Klopčič in Hamoen, 2010).

Primerjava lastnosti zunanjosti s plemenskimi biki drugih pasem je pomanjkljiva, saj so pri večini populacij v ocenjevanje zunanjosti vključene le prvesnice. Plemenski biki cikastega goveda so bili ob starosti 14,6 mesecev v povprečju v vihru primerljivo visoki (117,09 ± 4,63 cm) kot 12 mesecev stari biki španskega pirenaica (117,6 cm), italijanskega piemontese (118,8 cm) in francoskega limuzin (118,7 cm) goveda (Alberti in sod., 2008), ki spadajo med pasme z velikim telesnim okvirom (Felius in sod., 1995). Širina križa in telesna masa cikastih bikov (40,15 ± 3,54 cm; 319,42 ± 61,57 kg) sta bili podobni kot pri 12 mesecev starih bikih španskega goveda casina (40,9 cm; 321,4 kg) (Alberti in sod., 2008), ki spada med pasme z majhnim okvirom (Felius in sod., 1995).

Preglednica 4: Opisna statistika za lastnosti zunanjosti pri plemenskih bikih cikastega goveda

Lastnosti	n	Povprečje ± SD	Min	Max	KV (%)	Optimalna vrednost	Opis ocen 1 – 9
Starost (meseci)	330	14,60 ± 2,68	10,0	28,0	18,38		
Merjene lastnosti za telesni okvir							
Višina vihra (cm)	330	117,09 ± 4,63	103,0	131,0	3,95	≤115 cm	
Višina križa (cm)	330	120,20 ± 4,71	108,0	135,0	3,92		
Dolžina telesa (cm)	330	116,15 ± 6,71	85,0	135,0	5,78		
Obseg prsi (cm)	330	157,89 ± 10,49	134,0	190,0	6,64		
Širina prsi (cm)	330	38,75 ± 3,77	30,0	55,0	9,72		
Globina prsi (cm)	330	60,10 ± 4,19	49,0	72,0	6,98		
Širina križa (cm)	330	40,15 ± 3,54	30,0	54,0	8,82		
Telesna masa (kg)	330	319,42 ± 61,57	202,0	540,0	19,28		
Posamezne lastnosti za avtohtonost (1 – 9)							
Dolžina glave	330	6,15 ± 1,25	2	9	20,40	6 – 8	dolga – kratka
Plemenitost glave	179	5,78 ± 1,13	3	8	19,60		groba – plemenita
Izraženost oči	330	5,64 ± 0,92	3	9	16,30	6 – 8	slaba – močna
Debelina rogov	330	4,94 ± 1,29	1	9	26,02	6 – 8	debeli – tanki
Dolžina rogov	305	5,84 ± 1,28	3	9	21,90	6 – 9	dolgi – kratki
Usmerjenost rogov	330	5,25 ± 1,39	2	9	26,51	6 – 9	navzven – naprej
Vrat	330	5,02 ± 1,45	2	8	28,94	7 – 9	grob – plemenit
Izraženost podgrline	330	4,70 ± 1,43	2	8	30,41	6 – 9	močna – slaba
Barva plašča	330	5,39 ± 1,40	2	8	25,96		zelo temna – zelo svetla
Izraženost hrbtne lise	330	6,21 ± 1,39	1	9	22,40		močna – slaba
Izraženost pasov na zadnjih nogah	330	6,61 ± 1,71	1	9	25,90		močna – slaba
Izraženost pasov na prednjih nogah	330	7,40 ± 1,33	2	9	18,03		močna – slaba
Posamezne lastnosti za telesne oblike (1 – 9)							
Hrbet	330	4,66 ± 0,58	3	7	12,52	4 – 6	uleknjen – izbočen
Nagib križa	330	5,04 ± 0,57	3	7	11,40	4 – 6	nadgrajen – pobit
Kot skočnega sklepa	330	5,19 ± 0,70	3	8	13,56	4 – 6	strm – sabljast
Izraženost skočnega sklepa	330	6,21 ± 1,15	3	9	18,59	6 – 9	zadebeljen – tanek
Biclji	330	6,33 ± 0,97	3	8	15,26	6 – 8	mehki – strmi
Parklji	329	6,00 ± 0,99	3	9	16,46	6 – 9	nizki – visoki
Izjava rejca (1 – 5)							
Temperament	329	4,22 ± 0,78	2	5	18,43		nervozen – miren
Sestavljene lastnosti (1 – 9)							
Avtohtonost	329	6,36 ± 1,18	3	8	18,49		pincgavski – cikasti tip
Omišičenost	329	5,73 ± 1,13	2	9	19,80		
Telesne oblike	329	6,38 ± 1,01	3	8	15,80		

SD – standardni odklon, KV – koeficient variabilnosti

Srednje vrednosti za merjene lastnosti telesnega okvira pri prvesnicah (preglednica 5) so bile 126,49 ± 5,51 cm (višina vihra), 129,89 ± 5,56 cm (višina križa), 127,65 ± 6,13 cm (dolžina telesa) in 174,64 ± 9,80 cm (obseg prsi). Ocenjena variabilnost po posameznih lastnostih je bila večja pri prvesnicah v primerjavi s plemenskimi biki, kar je bilo pričakovano, saj je bilo število ocenjenih prvesnic večje in so bile manj strogo odbrane. Koeficient variabilnosti za merjene lastnosti pri prvesnicah je bil od 4,28 % do 5,61 %, za sestavljene lastnosti za avtohtonost 30,38 %, za omišičenost 20,32 %, za telesne oblike 20,20 % in za vime 22,67 %. Pri analiziranju ocen smo opazili zelo majhno zastopanost obeh ekstremnih ocen na lestvici, 1 oziroma 9.

Preglednica 5: Opisna statistika za lastnosti zunanjosti pri prvesnicah cikastega goveda

Lastnosti	n	Povprečje ± SD	Min	Max	KV (%)	Optimalna vrednost	Opis ocen 1 – 9
Starost (meseci)	1086	33,88 ± 5,29	21,0	48,0	15,61		
Merjene lastnosti za telesni okvir							
Višina vihra (cm)	1086	126,49 ± 5,51	112	142	4,35	≤ 125 cm	
Višina križa (cm)	1086	129,89 ± 5,56	114	146	4,28		
Dolžina telesa (cm)	1086	127,65 ± 6,13	105	146	4,81		
Obseg prsi (cm)	1086	174,64 ± 9,80	150	203	5,61		
Posamezne lastnosti za avtohtonost (1 – 9)							
Dolžina glave	1086	5,23 ± 1,31	2	9	25,13	6 – 8	dolga – kratka
Plemenitost glave	450	5,45 ± 1,27	2	9	23,33		groba – plemenita
Izraženost oči	1086	5,59 ± 1,02	2	9	18,28	6 – 8	slaba – močna
Debelina rogov	1064	4,73 ± 1,37	1	9	28,97	6 – 8	debeli – tanki
Dolžina rogov	869	5,08 ± 1,25	2	9	24,64	6 – 9	dolgi – kratki
Usmerjenost rogov	1064	5,15 ± 1,59	2	9	30,90	6 – 9	navzven – naprej
Vrat	1086	5,17 ± 1,36	2	9	26,33	7 – 9	grob – plemenit
Izraženost podgrline	1086	4,93 ± 1,33	2	9	26,91	6 – 9	močna – slaba
Barva plašča	1086	5,10 ± 1,37	1	9	26,87		zelo temna – zelo svetla
Izraženost hrbtne lise	1086	5,17 ± 1,53	1	9	29,62		močna – slaba
Izraženost pasov na zadnjih nogah	1086	5,40 ± 1,87	1	9	34,62		močna – slaba
Izraženost pasov na prednjih nogah	1086	6,25 ± 1,75	1	9	27,93		močna – slaba
Posamezne lastnosti za telesne oblike (1 – 9)							
Hrbet	1086	4,73 ± 0,60	2	7	12,66	4 - 6	uleknjen – izbočen
Nagib križa	1086	5,18 ± 0,79	2	8	15,25	4 – 6	nadgrajen – pobit
Kot skočnega sklepa	1086	5,54 ± 0,80	3	8	14,38	4 – 6	strm – sabljast
Izraženost skočnega sklepa	1086	5,56 ± 1,29	2	9	23,26	6 – 9	zadebeljen – tanek
Biclji	1086	5,89 ± 0,95	3	8	16,14	6 – 8	mehki – strmi
Parklji	1086	5,73 ± 0,96	2	9	16,67	6 - 9	nizki - visoki
Posamezne lastnosti za vime (1 – 9)							
Vime pod trebuhom	1086	4,90 ± 1,06	2	8	21,58	6 – 9	majhno – obsežno
Globina vimena	1086	5,39 ± 1,04	2	8	19,29	6 – 9	spuščeno – pripeto
Debelina prednjih seskov	1086	5,01 ± 0,97	2	8	19,30	4 – 6	tanki – debeli
Dolžina prednjih seskov	1086	5,36 ± 1,06	2	9	19,69	4 - 6	kratki – dolgi
Izjava rejca (1 - 5)							
Iztok mleka	1082	3,54 ± 0,59	1	5	16,51		počasen - hiter
Temperament	1082	3,75 ± 0,76	1	5	20,42		nervozen - miren
Sestavljene lastnosti (1 – 9)							
Avtohtonost	1086	5,03 ± 1,53	1	9	30,38		
Omišičenost	1086	5,47 ± 1,11	2	9	20,32		
Telesne oblike	1086	5,67 ± 1,14	2	8	20,20		
Vime	1086	5,01 ± 1,14	1	8	22,67		

SD – standardni odklon, KV – koeficient variabilnosti

Pri ocenjevanih lastnostih zunanjosti pri prvesnicah piemontese goveda na lestvici od 1 do 9 so bili izračunani koeficienti variabilnosti od 12 – 26 % (Mantovani, 2010). Primerjava ocenjevanih lastnosti zunanjosti cikastega goveda z drugimi pasmami je bila mogoča samo v primerih, ko se je uporabljala enaka lestvica za ocenjevanje. Pri ocenjevanju zunanjosti italijanskih avtohtonih pasem govedi rendena, valdostana in chianina uporabljajo lestvico od 1 do 5 (Mazza in sod., 2013; Mazza in sod., 2014, Forabosco in sod., 2004), pri piemontese govedu pa 1 – 9 (Mantovani in sod., 2010). Za ocenjevanje zunanjosti prvesnic asturiana de los valles goveda so razvili poseben sistem z lestvico od 1 do 9, s katerim ocenijo razvitost skeleta in omišičenost ter pasemske značilnosti (Gutiérrez in Goyache, 2002). Do razlik med pasmami prihaja tudi zaradi različnih definicij lastnosti z istim imenom.

Němcová in sod. (2011) ter Špehar in sod. (2012) so na osnovi ocen na linearni lestvici od 1 do 9, v skladu s pravili ICAR (International agreement…, 2012), analizirali lastnosti zunanjosti pri prvesnicah češkega holštajnskega in rjavega goveda. Srednje vrednosti za posamezne lastnosti zunanjosti pri prvesnicah holštajnskega (4,9 – 5,9) in rjavega goveda (4,73 – 5,86) so bile podobne srednjim vrednostim posameznih ocenjevanih lastnosti zunanjosti pri prvesnicah cikastega goveda (4,73 – 6,25).

Srednja vrednost za višino vihra pri prvesnicah cikastega goveda (126,49 ± 5,51 cm) nedvoumno kaže, da spada cika med pasme z manjšim do srednje velikim telesnim okvirom, saj je v vihru manjša v primerjavi s prvesnicami holštajnskega (143 cm), ameriškega rjavega (139 cm) in rdečega holštajnskega goveda (142 cm) (de Haas in sod., 2007) ter prvesnicami piemontese goveda (130,81 ± 3,64 cm) iz Italije (Mantovani in sod., 2010). V križu so bile prvesnice cikastega goveda visoke 129,89 cm, kar je manj od prvesnic rjavega goveda (139,8 cm) v Sloveniji (Špehar in sod., 2012).

Poleg povprečnih vrednosti ocen za lastnosti zunanjosti pri plemenskih bikih in prvesnicah, prikazujemo tudi povprečne vrednosti ocen za lastnosti zunanjosti ločeno za vsak tip (cikasti, delni cikasti, pincgavski). Razvrščanje živali v ustrezen tip poteka na osnovi sestavljene ocene za avtohtonost, ki zajema lastnosti zunanjosti kot je navedeno v preglednici 6. Razvrščanje živali v tip se izvede neposredno na koncu ocenjevanja.

Preglednica 6: Opis treh tipov cikastega goveda (Žan Lotrič in sod., 2010)

Tip	Sestavljena ocena za avtohtonost	Opis zunanjosti
Cikasti tip	7, 8, 9	fina konstitucija, manjši okvir, kratka glava, širok gobec, izražene velike oči, tanki in kratki rogovi usmerjeni naprej in navzgor, tanka nagubana koža na vratu, neizrazita podgrlina, tanke noge, obsežen vamp
Delni cikasti tip	4, 5, 6	srednje velik telesni okvir, združuje lastnosti zunanjosti cikastega in pincgavskega tipa, določene lastnosti zunanjosti so značilne za druge pasme (primesi)
Pincgavski tip	1, 2, 3	večji okvir, dolga glava, ozek gobec, neizrazite majhne oči, debeli in navzven usmerjeni rogovi, debela koža na vratu, obsežna podgrlina, debele noge, povit trup

Pri ocenjevanju sestavljene lastnosti za avtohtonost se, poleg posameznih ocen v sklopu za avtohtonost in zabeleženih napak, upoštevajo tudi »Navodila za presojo barvnih znakov cikastega goveda«, ki so bila objavljena leta 1935 v Službenem listu kraljevske banske uprave dravske banovine kot Banova uredba. Bistvene napake opisane v navodilih, ki žival »izključujejo« so črna ali presvetla (žemljasta ali rumenkasta) barva plašča, očitna pomešanost osnovne rjave barve z belo barvo, beli znaki na glavi in na nogah. Pri bikih še prevladujoča bela barva nad rjavo, bele lise v biclju, brezbarvni rogovi in popolnoma modrosiv gobec (Navodila za presojo…, 1935).

V preglednici 7 so deleži plemenskih bikov in prvesnic z napakami lastnosti zunanjosti. Največ plemenskih bikov (35,76 %) in prvesnic (18,78 %) je imelo prekinjeno hrbtno liso, ki se upošteva kot napaka v sklopu avtohtonih lastnosti. V sklopu napak telesnih oblik je bil največji delež plemenskih bikov (14,24 %) in prvesnic (18,14 %) z visoko nasajenim repom. Napake vimena zabeležene kot število paseskov je imelo 27,35 % prvesnic in stran štrleče seske je imelo 10,31 % prvesnic. Vse druge zabeležene napake v vseh sklopih so bile prisotne pri manjšem deležu živali v populaciji.

Preglednica 7: Delež živali z napakami za lastnosti zunanjosti

	Plemenski biki (n = 330)		Prvesnice (n = 1.086)	
Napake v sklopu avtohtonost	n	%	n	%
Temen gobec	1	0,30	55	5,06
Neustrezna barva plašča	2	0,61	14	1,29
Beli znaki na glavi	/	/	44	4,05
Beli znaki na nogah	2	0,61	75	6,91
Pikasto pisana	1	0,30	55	5,06
Prekinjena hrbtna lisa	118	35,76	204	18,78
Hrbtna lisa na križu	39	11,82	72	6,63
Napake v sklopu telesne oblike				
Razplečenost	3	0,91	44	4,05
Visoko nasajen rep	47	14,24	197	18,14
Vdolbina med sednicama	/	/	5	0,46
Kravja stoja	11	3,33	92	8,47
Razprti parklji	2	0,61	4	0,37
Napake v sklopu vime				0,00
Stopničasto vime	/	/	45	4,14
Lijakasti seski	/	/	32	2,95
Stran štrleči seski	/	/	112	10,31
Paseski	/	/	297	27,35
Medseski	/	/	14	1,29
Priseski	/	/	5	0,46

Od leta 2006 do 2014 je bilo ocenjenih in v analizo vključenih 330 plemenskih bikov (preglednica 8), ki so bili razvrščeni v cikasti tip (186), delni cikasti tip (142) in v pincgavski tip (2). Biki v pincgavskem tipu niso predvideni za pleme, zato bomo v nadaljevanju primerjali le plemenske bike v cikastem in delnem cikastem tipu. Plemenski biki v cikastem tipu so bili v povprečju nižji za 3,6 cm v vihru in 3,7 cm v križu od bikov v delnem cikastem tipu. Prav tako so imeli 4,8 cm krajšo dolžino telesa, 2 cm ožje prsi, 2,3 cm ožji križ in za 2,8 cm manjšo globino prsi. Plemenski biki v cikastem tipu so imeli 7,5 cm manjši obseg prsi in posledično so bili kar za 43 kg lažji od plemenskih bikov v delnem cikastem tipu pri skoraj isti starosti. Prav vse posamezne lastnosti za avtohtonost so bile v povprečju ocenjene kot bolj zaželene pri plemenskih bikih v cikastem tipu. Sestavljena lastnost za avtohtonost je bila za 1,9 ocene večja in s tem bolj zaželena pri bikih v cikastem tipu. Posamezne lastnosti za telesne oblike so bile zelo podobne pri obeh tipih cikastih bikov z izjemo izraženosti skočnega sklepa, ki je bil pri bikih v cikastem tipu v povprečju ocenjen z eno oceno bolje v primerjavi z delnim cikastim tipom. Sestavljena lastnost za telesne oblike je bila za 0,7 ocene boljša pri bikih v cikastem tipu. Biki v delnem cikastem tipu pa so imeli za 0,4 ocene boljšo omišičenost.

Preglednica 8: Opisna statistika za lastnosti zunanjosti pri plemenskih bikih treh tipov cikastega goveda

Lastnosti (povprečje ± SD)	Cikasti tip (n = 186)	Delni cikasti tip (n = 142)	Pincgavski tip (n = 2)
Starost (meseci)	14,33 ± 2,67	14,96 ± 2,67	14,50 ± 3,54
Merjene lastnosti za telesni okvir			
Višina vihra (cm)	115,47 ± 4,22	119,11 ± 4,22	124,00 ± 9,90
Višina križa (cm)	118,53 ± 4,26	122,28 ± 4,29	128,00 ± 9,90
Dolžina telesa (cm)	114,05 ± 6,76	118,81 ± 5,59	123,00 ± 5,66
Obseg prsi (cm)	154,61 ± 9,64	162,06 ± 10,04	167,00 ± 12,73
Širina prsi (cm)	37,85 ± 3,51	39,92 ± 3,78	38,00 ± 5,66
Globina prsi (cm)	58,88 ± 4,00	61,66 ± 3,90	62,50 ± 6,36
Širina križa (cm)	39,14 ± 3,51	41,43 ± 3,12	44,00 ± 5,66
Telesna masa (kg)	300,83 ± 54,97	342,99 ± 61,52	375,00 ± 73,54
Posamezne lastnosti za avtohtonost (1 – 9)			
Dolžina glave	6,35 ± 1,19	5,87 ± 1,29	6,50 ± 0,71
Plemenitost glave	6,42 ± 0,86	5,01 ± 0,93	5,00 ± 0,00
Izraženost oči	5,92 ± 0,86	5,29 ± 0,85	4,00 ± 1,41
Debelina rogov	5,29 ± 1,25	4,47 ± 1,18	6,00 ± 0,00
Dolžina rogov	6,20 ± 1,24	5,36 ± 1,16	5,50 ± 2,12
Usmerjenost rogov	5,59 ± 1,31	4,83 ± 1,38	4,50 ± 2,12
Vrat	5,71 ± 1,20	4,15 ± 1,23	2,00 ± 0,00
Izraženost podgrline	5,26 ± 1,31	4,00 ± 1,25	3,00 ± 0,00
Pigmentacija plašča	5,80 ± 1,28	4,89 ± 1,35	2,50 ± 0,71
Izraženost hrbtne lise	6,31 ± 1,34	6,06 ± 1,44	8,00 ± 0,00
Izraženost pasov na zadnjih nogah	6,81 ± 1,70	6,31 ± 1,69	8,50 ± 0,71
Izraženost pasov na prednjih nogah	7,49 ± 1,27	7,26 ± 1,41	8,50 ± 0,71
Posamezne lastnosti za telesne oblike (1 – 9)			
Hrbet	4,69 ± 0,53	4,63 ± 0,65	4,50 ± 0,71
Nagib križa	4,99 ± 0,51	5,09 ± 0,64	5,50 ± 0,71
Kot skočnega sklepa	5,18 ± 0,68	5,20 ± 0,74	5,00 ± 0,00
Izraženost skočnega sklepa	6,68 ± 0,99	5,64 ± 1,03	3,00 ± 0,00
Biclji	6,44 ± 0,85	6,20 ± 1,09	6,00 ± 0,00
Parklji	5,99 ± 0,99	6,01 ± 1,00	6,00 ± 0,00
Izjava rejca (1 – 5)			
Temperament	4,35 ± 0,73	4,04 ±0,81	4,00 ± 0,00
Sestavljene lastnosti (1 – 9)			
Avtohtonost	7,22 ± 0,42	5,28 ± 0,83	3,00 ± 0,00
Omišičenost	5,56 ± 1,08	5,96 ± 1,18	6,00 ± 1,41
Telesne oblike	6,69 ± 0,85	5,99 ± 1,06	5,50 ± 0,71

SD – standardni odklon

V preglednici 9 so prikazane srednje vrednosti za lastnosti zunanjosti pri 1.086 prvesnicah, ki so bile razvrščene v cikasti tip (213), delni cikasti (681) in pincgavski tip (192). Med prvesnicami vseh treh tipov je bila tudi razlika v starosti in sicer, prvesnice razvrščene v cikasti tip so bile 1,3 meseca mlajše od prvesnic razvrščenih v delni cikasti tip in 2,9 meseca mlajše od prvesnic v pincgavskem tipu. Prvesnice v cikastem tipu so bile v povprečju v vihru in križu nižje od prvesnic v delnem cikastem tipu za 4,5 cm oz. 4,8 cm in 10,9 cm oz. 11,2 cm od prvesnic v pincgavskem tipu. Prav tako so imele prvesnice v cikastem tipu za 4,6 cm krajšo dolžino telesa od prvesnic v delnem cikastem tipu in za 10,4 cm od prvesnic v pincgavskem tipu. Prvesnice v cikastem tipu so imele 6,5 cm manjši obseg prsi od prvesnic v delnem cikastem tipu in 15,6 cm od prvesnic v pincgavskem tipu. Prav vse posamezne lastnosti za avtohtonost so bile v povprečju ocenjene kot bolj zaželene pri prvesnicah v cikastem tipu. Sestavljena lastnost za avtohtonost je bila za 2,2 ocene bolje ocenjena pri cikastem tipu v primerjavi z delnim cikastim tipom in za 4,5 ocene bolje v primerjavi s pincgavskim tipom prvesnic, kar pomeni, da so imele prvesnice razvrščene v cikasti tip najbolj izražene avtohtone lastnosti. Ocene za posamezne lastnosti za telesne oblike so bile zelo podobne pri vseh treh tipih prvesnic, z izjemo izraženosti skočnega sklepa, ki je bil pri cikastem tipu v povprečju ocenjen za 1,2 ocene bolje v primerjavi z delnim cikastim tipom in 2,5 ocene bolje v primerjavi s pincgavskim tipom prvesnic. Sestavljena lastnost za telesne oblike je bila za 0,7 ocene boljša pri cikastem tipu v primerjavi z delnim cikastim in za 0,9 ocene boljša v primerjavi s pincgavskim tipom prvesnic. Prvesnice v cikastem tipu so imele za 0,2 ocene slabšo omišičenost v primerjavi z delnim cikastim in za 0,8 ocene slabšo omišičenost v primerjavi s pincgavskim tipom prvesnic. Sestavljena lastnost za vime je bila za 0,8 ocene boljša pri cikastem tipu prvesnic v primerjavi z delnim cikastim in za 1 oceno boljša v primerjavi s pincgavskim tipom prvesnic.

Merjene lastnosti telesnega okvira sedanje populacije prvesnic cikastega goveda smo primerjali s populacijami, ki so bile v preteklosti razširjene na območju, ki ustreza današnji razširjenosti cikastega goveda in so imele po opisu podobno barvo plašča. Ugotovili smo, da so prvesnice sedanje populacije v cikastem tipu, ki naj bi predstavljal prvotni tip cikastega goveda, v vihru (121,77 ± 3,78 cm) in križu (124,92 ± 3,92 cm) višje od krav bohinjskega (118 cm; 116 cm) in rdečega pisanega gorenjskega goveda (118 cm, 120 cm) (Povše, 1893) ter višje od krav bovškega (119 cm, 118 cm) in tolminskega goveda (120 cm, 114 cm) (Povše, 1894). Razlike lahko pojasnimo tudi z boljšimi rejskimi in krmnimi pogoji reje v sedanjem času. Ferčej (1947) je izmeril telesne mere kravam planinske in ravninske »zvrsti« gorenjskega pincgavca. Prvesnice v cikastem tipu v sedanji populaciji so v vihru višje od krav planinske »zvrsti« (119,5 cm). Krave ravninske »zvrsti« gorenjskega pincgavca pa so bile v vihru visoke 123,8 cm, kar je več kot pri sedanjih prvesnicah v cikastem tipu (121,77 ± 3,78 cm) in manj kot pri prvesnicah v delnem cikastem tipu (126,22 ± 4,64 cm). Glede na standardni odklon lahko zaključimo, da so prvesnice, v cikastem in delnem cikastem tipu v sedanji populaciji, po velikosti podobne populaciji krav gorenjskega pincgavskega goveda iz leta 1947.

Preglednica 9: Opisna statistika za lastnosti zunanjosti pri prvesnicah vseh treh tipov cikastega goveda

Lastnosti (povprečje ± SD)	Cikasti tip (n = 213)	Delni cikasti tip (n = 681)	Pincgavski tip (n = 192)
Starost (meseci)	32,61 ± 5,12	33,88 ± 5,38	35,29 ± 4,80
Merjene lastnosti za telesni okvir			
Višina vihra (cm)	121,77 ± 3,78	126,22 ± 4,64	132,69 ± 4,00
Višina križa (cm)	124,92 ± 3,92	129,68 ± 4,65	136,12 ± 3,82
Dolžina telesa (cm)	122,94 ± 4,67	127,53 ± 5,52	133,29 ± 4,91
Obseg prsi (cm)	167,83 ± 7,36	174,30 ± 8,81	183,41 ± 8,94
Posamezne lastnosti za avtohtonost (1 – 9)			
Dolžina glave	6,18 ± 1,10	5,16 ± 1,20	4,44 ± 1,28
Plemenitost glave	6,61 ± 0,85	5,25 ± 1,05	3,75 ± 1,03
Izraženost oči	6,26 ± 0,85	5,53 ± 0,96	5,02 ± 1,00
Debelina rogov	5,87 ± 1,14	4,65 ± 1,22	3,71 ± 1,19
Dolžina rogov	5,68 ± 1,14	5,04 ± 1,19	4,30 ± 1,27
Usmerjenost rogov	6,20 ± 1,26	5,08 ± 1,49	4,17 ± 1,58
Vrat	6,53 ± 0,84	5,14 ± 1,15	3,80 ± 1,06
Izraženost podgrline	6,02 ± 1,08	4,89 ± 1,21	3,87 ± 1,04
Pigmentacija plašča	5,63 ± 1,24	5,06 ± 1,37	4,64 ± 1,34
Izraženost hrbtne lise	5,48 ± 1,41	5,21 ± 1,50	4,68 ± 1,66
Izraženost pasov na zadnjih nogah	5,83 ± 1,72	5,45 ± 1,84	4,76 ± 1,98
Izraženost pasov na prednjih nogah	6,62 ± 1,51	6,29 ± 1,73	5,71 ± 1,93
Posamezne lastnosti za telesne oblike (1 – 9)			
Hrbet	4,74 ± 0,55	4,75 ± 0,60	4,68 ± 0,64
Nagib križa	4,99 ± 0,77	5,20 ± 0,77	5,31 ± 0,85
Kot skočnega sklepa	5,62 ± 0,74	5,53 ± 0,80	5,50 ± 0,84
Izraženost skočnega sklepa	6,74 ± 0,81	5,57 ± 1,09	4,20 ± 1,03
Biclji	5,94 ± 0,80	5,84 ± 0,96	6,01 ± 1,07
Parklji	5,78 ± 0,86	5,70 ± 0,93	5,77 ± 1,13
Posamezne lastnosti za vime (1 – 9)			
Vime pod trebuhom	5,51 ± 0,91	4,80 ± 1,04	4,58 ± 0,99
Globina vimena	5,86 ± 0,92	5,34 ± 0,99	5,07 ± 1,17
Debelina prednjih seskov	4,71 ± 0,88	5,03 ± 0,95	5,29 ± 1,04
Dolžina prednjih seskov	5,12 ± 1,04	5,40 ± 1,04	5,46 ± 1,10
Izjava rejca (1 – 5)			
Iztok mleka	3,82 ± 0,56	3,49 ± 0,57	3,43 ± 0,58
Temperament	3,95 ± 0,85	3,71 ± 0,74	3,66 ± 0,70
Sestavljene lastnosti (1 – 9)			
Avtohtonost	7,19 ± 0,41	5,00 ± 0,81	2,72 ± 0,47
Omišičenost	5,20 ± 0,88	5,41 ± 1,10	5,99 ± 1,22
Telesne oblike	6,27 ± 0,95	5,58 ± 1,11	5,31 ± 1,23
Vime	5,68 ± 0,99	4,90 ± 1,09	4,64 ± 1,14

SD – standardni odklon

Razliko med povprečnimi vrednostmi pri merjenih lastnostih pri prvesnicah vseh treh tipov lahko pojasnimo z oplemenjevanjem cikastega goveda s pincgavskim in s pretapljanjem z lisastim govedom v preteklosti. Pincgavsko in lisasto govedo imata večji telesni okvir, zato so živali v delnem cikastem in pincgavskem tipu večjega okvira. Živali v pincgavskem tipu imajo v genotipu največkrat večji delež pincgavskega goveda, kar je bilo potrjeno tudi z genetsko karakterizacijo na osnovi genetskih mikrosatelitnih označevalcev (Simčič in sod, 2013a, Simčič in sod, 2013b) in označevalcev SNP (Simčič in sod., 2015). Plemenski biki in prvesnice v cikastem tipu so manjšega telesnega okvira, kar je pozitivna lastnost za pasmo, katere tehnologija reje temelji na paši na strmih alpskih pašnikih. Živali manjšega telesnega okvira imajo, namreč, nižje postavljen center za težnost, kar omogoča, da so bolj stabilne na strmih pašnikih. Poleg tega imajo pasme z manjšim okvirom tudi manjše potrebe po vzdrževalni krmi (Communod in sod., 2013).

Viri variabilnosti

V preglednici 10 so prikazani viri variabilnosti na osnovi GLM analize za lastnosti zunanjosti pri plemenskih bikih, izračunani na osnovi modela 1. Sistematski vpliv leto ocenjevanja je bil statistično značilen pri štirih merjenih lastnostih (dolžina telesa, širina prsi, globina prsi, širina križa) in pri štirih posameznih ocenjevanih lastnostih. Leto ocenjevanja je statistično značilno vplivalo na sestavljeni lastnosti za omišičenost in za telesne oblike. Starost ob ocenjevanju je statistično značilno vplivala na vse merjene lastnosti in na šest posameznih ocenjevanih lastnosti za avtohtonost ter na sestavljeno lastnost za avtohtonost. Največji delež variabilnosti (R^2) za lastnosti zunanjosti pri plemenskih bikih cikastega goveda smo pojasnili z modelom 1 pri merjenih lastnostih (18 – 30 %). Delež pojasnjene variabilnosti pri posameznih lastnostih v sklopu avtohtonost je bil med 3 in 13 %, pri posameznih lastnostih za telesne oblike pa med 2 in 9 %. Delež pojasnjene variabilnosti za sestavljeno lastnost avtohtonost je bil 6 %. Lastnosti temperament in iztok mleka smo iz nadaljnjih analiz izključili, ker nista lastnosti zunanjosti in na njiju vplivajo drugačni dejavniki kot na lastnosti zunanjosti.

Preglednica 10: Viri variabilnosti za lastnosti zunanjosti pri plemenskih bikih cikastega goveda

	Viri variabilnosti (p-vrednosti)		R^2
	Leto ocenjevanja	Starost ob ocenjevanju	
Merjene lastnosti			
Višina vihra (cm)	ns	< 0,001	0,20
Višina križa (cm)	ns	< 0,001	0,20
Dolžina telesa (cm)	< 0,001	< 0,001	0,26
Obseg prsi (cm)	ns	< 0,001	0,27
Širina prsi (cm)	0,016	< 0,001	0,18
Globina prsi (cm)	< 0,001	< 0,001	0,30
Širina križa (cm)	0,001	< 0,001	0,25
Telesna masa (kg)	ns	< 0,001	0,28
Posamezne lastnosti za avtohtonost (1 – 9)			
Dolžina glave	0,001	0,003	0,13
Plemenitost glave	ns	ns	0,03
Izraženost oči	ns	0,002	0,05
Debelina rogov	ns	ns	0,03
Dolžina rogov	0,044	0,002	0,08
Usmerjenost rogov	< 0,001	ns	0,12
Vrat	ns	0,038	0,06
Izraženost podgrline	0,003	ns	0,07
Pigmentacija plašča	0,005	0,010	0,09
Izraženost hrbtne lise	ns	0,036	0,04
Izraženost pasov na zadnjih nogah	ns	ns	0,04
Izraženost pasov na prednjih nogah	ns	ns	0,03
Posamezne lastnosti za telesne oblike (1 – 9)			
Hrbet	ns	ns	0,04
Nagib križa	ns	ns	0,02
Kot skočnega sklepa	0,005	ns	0,07
Izraženost skočnega sklepa	ns	0,018	0,05
Biclji	ns	0,001	0,08
Parklji	0,001	ns	0,09
Sestavljene lastnosti (1 – 9)			
Avtohtonost	ns	0,025	0,06
Omišičenost	0,035	ns	0,05
Telesne oblike	0,002	ns	0,08

R^2 – koeficient determinacije, ns – ne značilen vpliv (p > 0,05)

V preglednici 11 so prikazani viri variabilnosti za lastnosti zunanjosti pri prvesnicah, izračunani na osnovi modela 2.

Preglednica 11: Viri variabilnosti za lastnosti zunanjosti pri prvesnicah cikastega goveda

Lastnosti	Viri variabilnosti (p-vrednosti)			R^2
	Leto ocenjevanja	Starost ob ocenjevanju	Čas po telitvi	
Merjene lastnosti za telesni okvir (cm)				
Višina vihra	< 0,001	< 0,001	< 0,001	0,17
Višina križa	< 0,001	< 0,001	< 0,001	0,15
Dolžina telesa	< 0,001	< 0,001	0,023	0,16
Obseg prsi	< 0,001	< 0,001	ns	0,14
Posamezne lastnosti za avtohtonost (1 – 9)				
Dolžina glave	0,003	< 0,001	ns	0,06
Plemenitost glave	ns	0,009	ns	0,03
Izraženost oči	< 0,001	ns	ns	0,03
Debelina rogov	< 0,001	< 0,001	0,001	0,07
Dolžina rogov	< 0,001	0,003	ns	0,04
Usmerjenost rogov	0,004	0,001	ns	0,03
Vrat	0,001	0,011	ns	0,05
Izraženost podgrline	< 0,001	0,002	ns	0,06
Pigmentacija plašča	0,005	ns	ns	0,02
Izraženost hrbtne lise	0,001	ns	ns	0,03
Izraženost pasov na zadnjih nogah	0,001	ns	ns	0,03
Izraženost pasov na prednjih nogah	0,001	0,021	ns	0,03
Posamezne lastnosti za telesne oblike (1 – 9)				
Hrbet	ns	ns	ns	0,01
Nagib križa	0,009	0,001	0,001	0,03
Kot skočnega sklepa	ns	0,007	ns	0,02
Izraženost skočnega sklepa	< 0,001	< 0,001	ns	0,08
Biclji	ns	0,006	ns	0,02
Parklji	< 0,001	ns	ns	0,04
Posamezne lastnosti za vime (1 – 9)				
Vime pod trebuhom	< 0,001	ns	< 0,001	0,09
Globina vimena	< 0,001	0,021	0,001	0,09
Debelina prednjih seskov	< 0,001	0,034	ns	0,04
Dolžina prednjih seskov	< 0,001	0,002	ns	0,06
Sestavljene lastnosti (1 – 9)				
Avtohtonost	< 0,001	< 0,001	0,043	0,12
Omišičenost	0,001	ns	0,050	0,03
Telesne oblike	< 0,001	0,001	ns	0,05
Vime	< 0,001	0,014	< 0,001	0,09

R^2 – koeficient determinacije, ns – ne značilen vpliv (p > 0,05)

Pri prvesnicah je bil sistematski vpliv leto ocenjevanja (preglednica 11) statistično značilen pri vseh merjenih lastnostih in tudi pri vseh posameznih ocenjevanih lastnostih za avtohtonost z izjemo lastnosti »plemenitost glave«. Prav tako je leto ocenjevanja statistično značilno vplivalo na vse posamezne lastnosti za vime. Leto ocenjevanja je statistično značilno vplivalo na vse sestavljene lastnosti, in sicer na avtohtonost, omišičenost, telesne oblike in na vime. Starost ob ocenjevanju je pri prvesnicah statistično značilno vplivala na vse merjene lastnosti in skoraj na vse posamezne lastnosti za avtohtonost. Prav tako je starost ob ocenjevanju statistično značilno vplivala na sestavljene lastnosti avtohtonost, telesne oblike in vime. Čas po telitvi je statistično značilno vplival na tri merjene lastnosti (višina vihra, višina križa, dolžina telesa), na debelino rogov in na vime pod trebuhom ter na globino vimena. Prav tako je čas po telitvi statistično značilno vplival na sestavljene lastnosti avtohtonost, omišičenost in vime.

Največji delež variabilnosti za lastnosti zunanjosti pri prvesnicah cikastega goveda smo pojasnili z modelom 2 pri merjenih lastnostih telesnega okvira (14 – 17 %). Delež pojasnjene variabilnosti je bil pri posameznih lastnostih za avtohtonost med 3 in 7 %, pri sestavljeni lastnosti za avtohtonost pa 12 % (Preglednica 11).

ICAR (International agreement…, 2012) priporoča analizo lastnosti zunanjosti z modelom, kjer naj bi bili vključeni vplivi starosti, stadija laktacije in sezone. Ocenjevalci naj ne bi korigirali ocen glede na starost, stadij laktacije, sezono, očeta in tehnologijo reje v času postopka ocenjevanja, ampak morajo oceniti le biološko izraženost lastnosti. Zabeležiti bi morali še način uhlevitve (prosta reja, vezana reja, reja z izpustom) in tip tal (beton, cement, les, pesek, guma, slama, pašnik), ker bi lahko vplivali na nekatere lastnosti zunanjosti.

Tudi pri analizah variance lastnosti zunanjosti pri prvesnicah italijanskih avtohtonih pasem valdostana (Mazza in sod., 2013), rendena (Mazza in sod., 2014) in piemontese (Mantovani in sod., 2010) so vključili oba vpliva, starost ob ocenjevanju in čas po telitvi. Poleg tega so vključili še interakcijo čreda-leto-ocenjevalec. Z navedenim modelom so pojasnili tudi večji delež variabilnosti (R^2 = 0,19 – 0,36) pri prvesnicah rendena v primerjavi s cikastim govedom. V model za analizo lastnosti zunanjosti španske pasme asturiana de los valles so vključili vplive črede, interakcijo ocenjevalec-leto-sezona, čas po telitvi in starost (Gutiérrez in Goyache, 2002). Pri prvesnicah holštajn-frizijskega goveda so v model za analizo variance ocen zunanjosti vključili naslednje vplive in sicer, interakcijo čreda-sezona ocenjevanja-ocenjevalec, ocenjevalec, sezona telitve in starost ob telitvi (Němcová in sod., 2011). Pri prvesnicah ameriškega rjavega goveda so v model za analizo variance ocen zunanjosti vključili vplive kot so interakcija čreda-leto-sezona, starost ob telitvi in ocenjevalec (Samoré in sod., 2010). V našem primeru interakcij med vplivi ni bilo mogoče upoštevati, ker je ocenjevalec samo eden. Poleg tega je število živali v čredah zelo majhno in je bilo zajeto zelo veliko število čred, zato smo vpliv črede vključili kot naključni vpliv.

Nekateri avtorji (npr. Dal Zotto in sod., 2007, Klopčič in Hamoen, 2010) priporočajo tudi vključitev telesne kondicije v model kot vpliv pri analizi variance lastnosti zunanjosti. Telesna kondicija predstavlja pokritost s podkožno maščobo oziroma lojem, ki ga otipamo na predelu korena repa in ledvenih vretenc, in lahko vpliva na ocene zunanjosti, še posebno, ko so živali v preskromni ali v predobri kondiciji. Menimo, da bi bilo potrebno ocenjevanje telesne kondicije vpeljati tudi v ocenjevanje zunanjosti prvesnic in plemenskih bikov cikaste pasme.

Ocenjeni deleži variance

Deleže pojasnjene variance smo z modelom živali (model 3) ocenili samo za prvesnice (preglednica 12), ker je bilo podatkov o ocenah zunanjosti plemenskih bikov premalo (330 živali) in struktura podatkov ni bila primerna za zanesljivo oceno. Desna asimetričnost je bila posledica ocenjevanja samo odbranih potencialnih plemenskih bikov iz populacije (cikasti in delni cikasti tip), ki imajo samo višje ocene na lestvici od 1 do 9. Poleg tega, raziskovalci v literaturi, navajajo deleže varianc samo za lastnosti zunanjosti prvesnic. Pri prvesnicah so bili ocenjeni dednostni deleži za vse lastnosti zunanjosti med 0,17 in 0,87 (preglednica 12), delež pojasnjene variance z vplivom črede pa je bil med 0,01 in 0,27. Ocenjeni dednostni deleži za merjene lastnosti so bili od 0,48 do 0,79, za sklop posameznih lastnosti za avtohtonost od 0,37 do 0,87, za sklop posameznih lastnosti za telesne oblike od 0,17 do 0,70 in za sklop posameznih lastnosti za vime od 0,26 do 0,51. Ocenjeni dednostni deleži za sestavljene lastnosti avtohtonost, omišičenost, telesne oblike in vime so bili 0,62, 0,28, 0,20 in 0,30.

Deleži pojasnjene variance za lastnosti telesnega okvira

Ocenjena dednostna deleža (h^2) za višino vihra in za višino križa sta bila pri prvesnicah cikastega goveda 0,78 ± 0,06 in 0,79 ± 0,06. Manjši h^2 za višino vihra so ocenili pri prvesnicah piemontese goveda (0,31 ± 0,02) (Mantovani in sod., 2010). Podoben h^2 za višino križa so ocenili pri prvesnicah holštajnskega (0,69 ± 0,03), ameriškega rjavega (0,64 ± 0,02) in rdečega holštajnskega goveda (0,74 ± 0,03) iz Švice (de Haas in sod., 2007), medtem ko je bil ocenjen h^2 manjši pri prvesnicah rjavega goveda (0,46) (Špehar in sod., 2012). Manjši h^2 za višino križa so ocenili pri prvesnicah rendena (0,52) (Mazza in sod., 2014), ameriškega rjavega (0,32) (Dal Zotto in sod., 2007) in češkega holštajn-frizijskega goveda (0,45) (Němcová in sod., 2011).

Ocenjeni dednostni delež za dolžino telesa je bil pri prvesnicah cikastega goveda 0,66 ± 0,06. Manjši h^2 za dolžino telesa so ocenili pri prvesnicah rendena goveda (0,41) (Mazza in sod., 2014). Ocenjeni h^2 za obseg prsi je bil pri prvesnicah cikastega goveda 0,48 ± 0,06, kar je le nekoliko več od h^2 za obseg prsi pri prvesnicah holštajnskega (0,38 ± 0,02), ameriškega rjavega (0,35 ± 0,02) in rdečega holštajnskega goveda (0,36 ± 0,02) iz Švice (de Haas in sod., 2007).

Preglednica 12: Deleži komponent variance za lastnosti zunanjosti pri prvesnicah cikastega goveda

Lastnosti	h^2	Čreda (s_h^2)	Ostanek (e^2)
Merjene lastnosti za telesne oblike			
Višina vihra	0,78 ± 0,06	0,08 ± 0,03	0,14 ± 0,05
Višina križa	0,79 ± 0,06	0,09 ± 0,03	0,12 ± 0,05
Dolžina telesa	0,66 ± 0,06	0,14 ± 0,03	0,20 ± 0,05
Obseg prsi	0,48 ± 0,06	0,25 ± 0,04	0,27 ± 0,05
Posamezne lastnosti za avtohtonost			
Dolžina glave	0,53 ± 0,05	0,06 ± 0,02	0,41 ± 0,05
Plemenitost glave	0,66 ± 0,07	0,05 ± 0,02	0,29 ± 0,07
Izraženost oči	0,53 ± 0,05	0,06 ± 0,02	0,42 ± 0,04
Debelina rogov	0,66 ± 0,06	0,07 ± 0,02	0,27 ± 0,05
Dolžina rogov	0,59 ± 0,05	0,04 ± 0,03	0,38 ± 0,04
Usmerjenost rogov	0,37 ± 0,05	0,05 ± 0,02	0,58 ± 0,05
Vrat	0,63 ± 0,06	0,04 ± 0,03	0,33 ± 0,05
Izraženost podgrline	0,68 ± 0,06	0,08 ± 0,03	0,25 ± 0,05
Pigmentacija plašča	0,73 ± 0,05	0,03 ± 0,01	0,24 ± 0,05
Izraženost hrbtne lise	0,87 ± 0,05	0,02 ± 0,01	0,11 ± 0,05
Izraženost pasov na zadnjih nogah	0,86 ± 0,05	0,02 ± 0,01	0,12 ± 0,04
Izraženost pasov na prednjih nogah	0,76 ± 0,06	0,01 ± 0,006	0,23 ± 0,05
Posamezne lastnosti za telesne oblike			
Hrbet	0,20 ± 0,05	0,08 ± 0,02	0,72 ± 0,05
Nagib križa	0,32 ± 0,06	0,01 ± 0,007	0,67 ± 0,06
Kot skočnega sklepa	0,17 ± 0,03	0,12 ± 0,03	0,71 ± 0,04
Izraženost skočnega sklepa	0,70 ± 0,05	0,06 ± 0,02	0,24 ± 0,06
Biclji	0,20 ± 0,04	0,11 ± 0,03	0,70 ± 0,04
Parklji	0,20 ± 0,03	0,20 ± 0,03	0,60 ± 0,04
Posamezne lastnosti za vime			
Vime pod trebuhom	0,26 ± 0,04	0,12 ± 0,03	0,62 ± 0,04
Globina vimena	0,28 ± 0,05	0,15 ± 0,03	0,57 ± 0,04
Debelina prednjih seskov	0,33 ± 0,05	0,10 ± 0,02	0,57 ± 0,05
Dolžina prednjih seskov	0,51 ± 0,06	0,06 ± 0,02	0,43 ± 0,05
Sestavljene lastnosti			
Avtohtonost	0,62 ± 0,06	0,10 ± 0,03	0,28 ± 0,05
Omišičenost	0,28 ± 0,07	0,27 ± 0,04	0,45 ± 0,06
Telesne oblike	0,20 ± 0,03	0,09 ± 0,02	0,71 ± 0,04
Vime	0,30 ± 0,05	0,13 ± 0,03	0,57 ± 0,04

h^2 = dednostni delež – delež pojasnjene variance z aditivnim genetskim vplivom

Deleži variance za sklop posameznih lastnosti za avtohtonost

Ocenjeni dednostni delež (h^2) za dolžino glave je bil pri prvesnicah cikastega goveda 0,53 ± 0,05. Manjši h^2 za dolžino glave so ocenili pri prvesnicah asturiana de los valles (0,25 ± 0,02) (Gutiérrez in Goyache, 2002) in piemontese (0,15 ± 0,02) (Mantovani in sod., 2010). Ocenjeni h^2 za sestavljeno lastnost avtohtonost je bil pri prvesnicah cikastega goveda 0,62 ± 0,06. Pri prvesnicah španskega asturiana de los valles goveda so ocenili h^2 za lastnost imenovano pasemske značilnosti (0,33 ± 0,02) in združuje barvo plašča in splošen izgled živali glede na pasemski standard (Gutiérrez in Goyache, 2002).

Deleži variance za sklop posameznih lastnosti za telesne oblike

Ocenjeni dednostni delež (h^2) za hrbet je bil pri prvesnicah cikastega goveda 0,20 ± 0,05. Manjši h^2 za hrbet so ocenili pri prvesnicah asturiana de los valles (0,11 ± 0,01) (Gutiérrez in Goyache, 2002), piemontese (0,07 ± 0,01) (Mantovani in sod., 2010), slovenskega rjavega (0,16) (Špehar in sod., 2012) in ameriškega rjavega goveda (0,10) (Dal Zotto in sod., 2007). Ocenjeni h^2 za nagib križa je bil pri prvesnicah cikastega goveda 0,32 ± 0,06. Podoben h^2 za nagib križa so ocenili tudi pri prvesnicah rendena (0,36) (Mazza in sod., 2014) in češkega holštajn-frizijskega goveda (0,34) (Němcová in sod., 2011) medtem, ko je bil h^2 pri prvesnicah slovenskega rjavega goveda 0,22 (Špehar in sod., 2012) in 0,24 pri prvesnicah ameriškega rjavega goveda (Dal Zotto in sod., 2007). Ocenjeni dednosti delež za sestavljeno lastnost telesne oblike je bil pri prvesnicah cikastega goveda 0,20 ± 0,03, podoben kot pri prvesnicah rendena (0,18) goveda (Mazza in sod., 2014).

Ocenjeni dednostni delež za kot skočnega sklepa je bil pri prvesnicah cikastega goveda 0,17 ± 0,03. Podoben h^2 za kot skočnega sklepa so ocenili tudi pri prvesnicah rendena (0,21) (Mazza in sod., 2014), piemontese (0,12 ± 0,02) (Mantovani in sod., 2010), slovenskega rjavega (0,13) (Špehar in sod., 2012), ameriškega rjavega (0,14) (Dal Zotto in sod., 2007) in češkega holštajn-frizijskega goveda (0,16) (Němcová in sod., 2011). Ocenjeni h^2 za izraženost skočnega sklepa je bil pri prvesnicah cikastega goveda 0,70 ± 0,05. Manjši h^2 za izraženost skočnega sklepa so ocenili pri prvesnicah rjavega goveda (0,11) (Špehar in sod., 2012) in ameriškega rjavega goveda (0,08) (Dal Zotto in sod., 2007). Ocenjeni dednostni delež za parklje je bil pri prvesnicah cikastega goveda 0,20 ± 0,03. Manjši h^2 za parklje so ocenili pri prvesnicah rendena (0,12) (Mazza in sod., 2014), piemontese (0,09 ± 0,01) (Mantovani in sod., 2010), rjavega (0,04) (Špehar in sod., 2012), ameriškega rjavega (0,09) (Dal Zotto in sod., 2007) in češkega holštajn-frizijskega goveda (0,10) (Němcová in sod., 2011).

Deleži variance za sklop posameznih lastnosti za vime

Ocenjeni dednosti delež za vime pod trebuhom je bil pri prvesnicah cikastega goveda 0,26 ± 0,04, podoben kot pri prvesnicah rendena (0,32) (Mazza in sod., 2014) in češkega holštajn-frizijskega goveda (0,24) (Němcová in sod., 2011) ter večji kot pri prvesnicah rjavega (0,14) (Špehar in sod., 2012), ameriškega rjavega (0,14) (Dal Zotto in sod., 2007) in francoskega holštajnskega goveda (0,18) (Rupp in Boichard, 1999). Ocenjeni dednosti delež za sestavljeno lastnost vime je bil pri prvesnicah cikastega goveda 0,30 ± 0,05, podoben kot pri prvesnicah rendena (0,37) (Mazza in sod., 2014) in večji kot pri prvesnicah rjavega goveda (0,16) (Špehar in sod., 2012).

Prav tako je bil ocenjen dednosti delež za globino vimena pri prvesnicah cikastega goveda (0,28 ± 0,05) podoben kot pri prvesnicah rendena (0,27) (Mazza in sod., 2014), rjavega

(0,22) (Špehar in sod., 2012), ameriškega rjavega (0,23) (Dal Zotto in sod., 2007), češkega holštajn-frizijskega (0,32) (Němcová in sod., 2011) in francoskega holštajnskega (0,29) goveda (Rupp in Boichard, 1999). Ocenjeni dednosti delež za dolžino prednjih seskov pri prvesnicah cikastega goveda (0,51 ± 0,06) je bil veliko večji v primerjavi s prvesnicami rendena (0,34) (Mazza in sod., 2014), rjavega (0,33) (Špehar in sod., 2012), ameriškega rjavega (0,32) (Dal Zotto in sod., 2007), češkega holštajn-frizijskega (0,28) (Němcová in sod., 2011) in francoskega holštajnskega goveda (0,30) (Rupp in Boichard, 1999).

Deleži variance za sestavljeno lastnost omišičenost

Ocenjeni dednosti delež za omišičenost je bil pri prvesnicah cikastega goveda 0,28 ± 0,07 in je bil podoben kot pri rendena (0,31) (Mazza in sod., 2014) in asturiana de los valles govedu (0,22 ± 0,01) (Gutiérrez in Goyache, 2002). Ocenjeni dednosti delež za omišičenost pri prvesnicah cikastega goveda je bil večji kot pri prvesnicah rjavega goveda (0,16) (Špehar in sod., 2012) ter manjši kot pri prvesnicah ameriškega rjavega (0,42 ± 0,02) in rdečega holštajnskega goveda (0,59 ± 0,03) iz Švice (de Haas in sod., 2007). Ocenjeni dednostni deleži za isto lastnost se lahko razlikujejo med populacijami (pasmami) zaradi različnega načina ocenjevanja, različne usklajenosti ocenjevalcev, različnih statističnih modelov in strukture ter čiščenja podatkov.

Deleži variance za čredo in ostanek

Delež pojasnjene variance z vplivom črede za lastnosti zunanjosti pri prvesnicah je bil od 1 do 27 % (preglednica 12). Delež pojasnjene variance z vplivom črede za merjene lastnosti je bil od 8 do 25 %, za posamezne lastnosti za avtohtonost od 1 do 8 %, za posamezne lastnosti za telesne oblike od 1 do 20 % in za posamezne lastnosti za vime od 6 do 15 %. Deleži pojasnjene variance z vplivom črede za sestavljene lastnosti avtohtonost, omišičenost, telesne oblike in vime so bili 10 %, 27 %, 9 % in 13 %. Delež variance ostanka je bil od 11 – 72 %.

Ocenjene genetske in fenotipske korelacije

Preglednica 13: Ocenjene genetske korelacije (nad diagonalo) in fenotipske korelacije (pod diagonalo) med merjenimi lastnostmi

Lastnost	Višina vihra	Višina križa	Dolžina telesa	Obseg prsi
Višina vihra		0,99 ± 0,01	0,98 ± 0,01	0,89 ± 0,03
Višina križa	0,98		0,97 ± 0,01	0,87 ± 0,04
Dolžina telesa	0,85	0,86		0,93 ± 0,03
Obseg prsi	0,69	0,69	0,77	

Ocenjene genetske in fenotipske korelacije med merjenimi lastnostmi za velikost okvirja (preglednica 13) so bile pozitivne in zelo visoke, vse nad 0,69. Glede na to, da so bile ocenjene genetske in fenotipske korelacije med vsemi merjenimi lastnostmi zelo visoke, bi bilo smiselno zmanjšati število merjenih lastnosti ob ocenjevanju. Navodila za ocenjevanje zunanjosti po ICAR (International agreement…, 2012) namreč, izmed vseh merjenih lastnosti pri ciki, predvidevajo samo merjenje višine križa. Tudi pri prvesnicah rendena (Mazza in sod., 2014) so ocenili zelo visoke genetske (nad 0,79) in visoke fenotipske korelacije (nad 0,53) med lastnostmi telesnega okvira. Pozitivne nekoliko manjše ocenjene genetske korelacije med višino križa in obsegom prsi so ocenili pri prvesnicah holštajnskega (0,45), ameriškega rjavega (0,34) in rdečega holštajnskega goveda (0,54) (de Haas in sod., 2007).

Sklop posameznih ocenjevanih lastnosti za avtohtonost smo za oceno variance razdelili na tri skupine. Prva skupina je vključevala posamezne lastnosti glave in rogov, druga je vključevala posamezni lastnosti vratu in tretja skupina je vključevala posamezne lastnosti barvnega vzorca plašča.

Preglednica 14: Ocenjene genetske korelacije (nad diagonalo) in fenotipske korelacije (pod diagonalo) med posameznimi lastnostmi za avtohtonost iz prve skupine

Lastnost	Dolžina glave	Plemenitost glave	Izraženost oči	Debelina rogov	Dolžina rogov	Usmerjenost rogov
Dolžina glave		0,38 ±0,09	0,68 ± 0,05	0,21 ± 0,08	-0,10 ± 0,09	0,17 ± 0,10
Plemenitost glave	0,38		0,71 ± 0,06	0,68 ± 0,06	0,46 ± 0,06	0,65 ± 0,07
Izraženost oči	0,46	0,47		0,29 ± 0,07	0,31 ± 0,08	0,35 ± 0,09
Debelina rogov	0,15	0,51	0,13		0,52 ± 0,06	0,58 ± 0,08
Dolžina rogov	0,06	0,27	0,12	0,46		0,66 ± 0,08
Usmerjenost rogov	0,14	0,46	0,27	0,40	0,47	

Ocenjene fenotipske korelacije med posameznimi lastnostmi glave (preglednica 14) so bile nizke do zmerne in vse pozitivne, od 0,06 (dolžina rogov – dolžina glave) do 0,51 (debelina rogov – plemenitost glave). V primerjavi z ocenjenimi genetskimi korelacijami so bile odgovarjajoče fenotipske korelacije manjše. Bolj izražene oči so imele živali s krajšo (0,68 ± 0,05) in bolj plemenito glavo (0,71 ± 0,06). Glava je bila bolj plemenita, ko so bili rogovi tanjši (0,68 ± 0,06).

Preglednica 15: Ocenjene genetske korelacije (nad diagonalo) in fenotipske korelacije (pod diagonalo) med posameznima lastnostma za avtohtonost iz druge skupine

Lastnost	Vrat	Izraženost podgrline
Vrat		0,88 ± 0,04
Izraženost podgrline	0,63	

Ocenjena fenotipska korelacija med lastnostma vrat in izraženost podgrline (preglednica 15) je bila visoka in pozitivna (0,63). Živali s plemenitim vratom so imele slabo izraženo podgrlino. Prav tako so imele živali z grobim vratom zelo izraženo podgrlino.

Preglednica 16: Ocenjene genetske korelacije (nad diagonalo) in fenotipske korelacije (pod diagonalo) med posameznimi lastnostmi za avtohtonost iz tretje skupine

Lastnost	Barva plašča	Izraženost hrbtne lise	Izraženost pasov na zadnjih nogah	Izraženost pasov na prednjih nogah
Barva plašča		0,15 ± 0,04	0,10 ± 0,03	0,04 ± 0,05
Izraženost hrbtne lise	0,10		0,96 ± 0,02	0,91 ± 0,02
Izraženost pasov na zadnjih nogah	0,09	0,86		0,95 ± 0,02
Izraženost pasov na prednjih nogah	0,03	0,79	0,82	

Ocenjene genetske in fenotipske korelacije med posameznimi lastnostmi za barvo plašča (preglednica 16) so bile šibke do zelo visoke (0,96; izraženost hrbtne lise – izraženost pasov na zadnjih nogah) in vse pozitivne. Prvesnice, ki so imele širšo hrbtno liso so imele tudi širše pasove na zadnjih in prednjih nogah. Prav tako so imele živali s širšim belim pasom na zadnjih nogah tudi širši bel pas na prednjih nogah.

Preglednica 17: Ocenjene genetske korelacije (nad diagonalo) in fenotipske korelacije (pod diagonalo) med posameznimi lastnostmi za telesne oblike in sestavljeno lastnostjo telesne oblike

Lastnost	Hrbet	Nagib križa	Kot skočnega sklepa	Izraženost skočnega sklepa	Biclji	Parklji	Telesne oblike (sestavljena)
Hrbet		0,27 ± 0,15	-0,07 ± 0,15	0,14 ± 0,08	-0,08 ± 0,12	-0,16 ± 0,13	0,28 ± 0,13
Nagib križa	0,24		0,23 ± 0,11	-0,25 ± 0,08	-0,10 ± 0,13	-0,11 ± 0,13	-0,55 ± 0,12
Kot skočnega sklepa	-0,04	-0,04		0,07 ± 0,06	-0,70 ± 0,09	-0,40 ± 0,10	-0,35 ± 0,13
Izraženost skočnega sklepa	0,08	-0,11	0,10		-0,22 ± 0,12	-0,46 ± 0,10	0,18 ± 0,09
Biclji	0,04	-0,07	-0,28	-0,10		0,90 ± 0,05	0,62 ± 0,08
Parklji	0,01	-0,07	-0,18	-0,24	0,60		0,62 ± 0,07
Telesne oblike (sestavljena)	0,26	-0,18	-0,28	0,08	0,55	0,51	

Večina ocenjenih fenotipskih korelacij med lastnostmi za telesne oblike (preglednica 17) je bilo negativnih šibkih do zmernih od -0,04 (kot skočnega sklepa - hrbet in kot skočnega sklepa - nagib križa) do -0,28 (kot skočnega sklepa - biclji in kot skočnega sklepa - telesne oblike). Ocenjene pozitivne fenotipske korelacije so bile nizke do visoke. Pozitivna genetska korelacija je bila največja med biclji in parklji (0,90 ± 0,05), kar pomeni, da so imele živali z mehkimi biclji nizke parklje, živali s strmimi biclji pa visoke parklje. Največja ocenjena negativna genetska korelacija je bila med kotom skočnega sklepa in biclji (-0,70 ± 0,09), kar pomeni, da so imele živali s strmim kotom skočnega sklepa visoke parklje in živali s sabljastim kotom nizke parklje. Visoke ocenjene genetske korelacije med sestavljeno lastnostjo telesne oblike in posameznimi lastnostmi so bile z biclji (0,62 ± 0,08), parklji (0,62 ± 0,07) in nagibom križa (-0,55 ± 0,12). To pomeni, da so imele živali z dobro ocenjeno telesno obliko strme biclje, visoke parklje in nadgrajen križ. Špehar in sod. (2012) so ocenili podobne genetske korelacije med kotom in izraženostjo skočnega sklepa (0,06) in med kotom skočnega sklepa in parklji (-0,33) pri prvesnicah slovenskega rjavega goveda. Němcová in sod. (2011) so ocenili podobne fenotipske in genetske korelacije med nagibom križa in parklji (-0,06; -0,04) ter genetske korelacije med nagibom križa in kotom skočnega sklepa (-0,07) pri prvesnicah češkega holštajn-frizijskega goveda.

Preglednica 18: Ocenjene genetske korelacije (nad diagonalo) in fenotipske korelacije (pod diagonalo) med posameznimi lastnostmi za vime in sestavljeno lastnostjo vime

Lastnost	Vime pod trebuhom	Globina vimena	Debelina prednjih seskov	Dolžina prednjih seskov	Vime (sestavljena)
Vime pod trebuhom		0,84 ± 0,06	-0,53 ± 0,11	-0,55 ± 0,09	0,96 ± 0,02
Globina vimena	0,60		-0,79 ± 0,08	-0,82 ± 0,06	0,90 ± 0,03
Debelina prednjih seskov	-0,16	-0,38		0,87 ± 0,04	-0,69 ± 0,08
Dolžina prednjih seskov	-0,26	0,45	0,65		-0,69 ± 0,06
Vime (sestavljena)	0,81	0,77	-0,28	-0,39	

Ocenjene fenotipske korelacije med lastnostmi za vime (preglednica 18) so bile zmerne in negativne od -0,39 (vime – dolžina prednjih seskov) do zelo visoke pozitivne 0,81 (vime – vime pod trebuhom). Vse ocenjene genetske korelacije so bile zelo visoke do visoke, tako pozitivne kot negativne. Dobro (funkcionalno) vime je bilo obsežno pod trebuhom (0,96 ± 0,02), dobro pripeto (0,90 ± 0,03) s tankimi (-0,69 ± 0,08) in krajšimi seski (-0,69 ± 0,06). Pripetost vimena pod trebuhom in globina vimena sta bili zelo povezani (0,84 ± 0,06), prav tako dolžina in debelina prednjih seskov (0,87 ± 0,04). Krave z genetskimi predispozicijami za slabo pripeto vime imajo navadno globlje vime. Němcová in sod. (2011) so ocenili nekoliko nižje fenotipske in genetske korelacije med vimenom pod trebuhom in globino vimena (0,44; 0,75) pri prvesnicah češkega holštajn-frizijskega goveda. Mazza in sod. (2011) so ocenili nekoliko nižjo fenotipsko in genetsko korelacijo med sestavljeno lastnostjo vime in posamezno lastnostjo vime pod trebuhom (0,68; 0,78) pri prvesnicah rendena goveda.

SKLEPI

Razvrščanje živali v tip poteka na osnovi ocene za sestavljeno lastnost avtohtonost in se izvede takoj po ocenjevanju, kar onemogoča, da bi upoštevali morebitne vplive okolja. Ugotovili smo, da na lastnosti zunanjosti in posledično na razvrstitev živali v tip pomembneje vplivajo najmanj naslednji dejavniki: leto ocenjevanja, starost in stadij laktacije. Ocenjeni dednostni deleži za vse lastnosti zunanjosti so bili v okviru pričakovanega in so primerljivi s tistimi navedenimi v literaturi. Največje dednostne deleže smo ocenili pri merjenih lastnostih za velikost okvirja in pri posameznih ocenjevanih lastnostih za avtohtonost. Razvrstitev živali v ustrezen tip, bi bilo zaradi tega, potrebno opraviti po izvrednotenju ocen za lastnosti zunanjosti in izključitvi vplivov okolja. S tem bi dobili bolj pravilne razvrstitve živali v tip. Plemenske vrednosti bi lahko bolje služile kot osnova za selekcijo, saj predstavljajo večjo variabilnost kot delitev živali na tri tipe.

Predlagamo, da bi ob ocenjevanju zunanjosti bolj upoštevali pravila ICAR-ja in ocenili tudi telesno kondicijo živali in jo vključili kot vpliv v postopku genetskega vrednotenja. Tudi pri drugih pasmah že upoštevajo telesno kondicijo. Glede na to, da so bile ocenjene genetske korelacije med nekaterimi lastnostmi zelo visoke je smiselno zmanjšati število merjenih lastnosti, kar bi poenostavilo postopek ocenjevanja.

Ocenjene dednostne deleže za lastnosti zunanjosti smo primerjali z dednostnimi deleži pri prvesnicah drugih avtohtonih, mlečnih in kombiniranih pasem govedi. Razlike so bile majhne, zato lahko zaključimo, da so ocenjeni genetski parametri primerni za napovedovanje plemenskih vrednosti za lastnosti zunanjosti pri prvesnicah cikastega goveda. Rezultati te raziskave so pokazali, da je genetski napredek nedvoumno mogoč pri vseh vključenih lastnostih zunanjosti, zaradi relativno velikih dednostih deležev in velike genetske variabilnosti.

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2.2 O IZVORU SLOVENSKEGA CIKASTEGA GOVEDA

On the origin of the Slovenian Cika cattle

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Journal of Animal Breeding and Genetics, 2013, 130, 6: 487-495

Izvleček:

V letu 2002 je bilo ugotovljeno, da so se nekatere živali cikastega goveda iz hribovitih območij v Sloveniji izognile uradni politiki pretapljanja pasme. V članku prikazujemo genetsko karakterizacijo, da bi ocenili status avtohtone pasme. Primerjali smo genotipe na 14 mikrosatelitnih označevalcih pri 150 živalih cikastega goveda z genotipi 16 pasem govedi iz srednje Evrope. Pokazali smo, da je cikasto govedo genetsko enako raznoliko kot druge vzhodno alpske pasme, bolj raznoliko od avstrijskega lisastega goveda, vendar manj od balkanske buše. Analiza s programom Structure je zaznala primesi pincgavskega goveda pri več živalih, vendar je pokazala tudi edinstveno genetsko identiteto cikastega goveda. Ta analiza omogoča izbor genetsko najbolj čistih živali cikastega goveda ocenjeno z naborom mikrosatelitnih označevalcev. Izvorno cikasto govedo oblikuje skupino vzhodno alpskih pasem skupaj s pincgavskim in pustariškim govedom. Cikasto govedo je potrebno obravnavati kot avtentično pasmo in dragocen genetski vir, ki ponuja jasne priložnosti za trajnostno kmetijstvo in ohranjanje krajine na obrobnih in gorskih območjih.

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ORIGINAL ARTICLE

On the origin of the Slovenian Cika cattle

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Balkan cattle; cattle; genetic diversity; genetic structure; microsatellite; Slovenia.

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Summary

In 2002, it was discovered that several Cika cattle in the mountain areas of Slovenia had escaped the official policy of cross-breeding. Here, we report a genetic characterization to assess their status as autochthonous breed. We compared genotypes for 14 microsatellite markers in 150 Cika cattle individuals with data from 16 Central European cattle breeds. We show that Cika cattle are genetically as diverse as other Eastern Alpine breeds, are more diverse than Austrian Simmental but less than the Balkan Busha cattle. STRUCTURE analysis showed Pinzgauer admixture in several individuals but also indicated a unique genetic identity for Cika. This analysis also allowed a selection of the most genetically pure Cika individuals as assessed by the panel of microsatellites. These original Cika cattle form an Eastern Alpine breed cluster together with Pinzgauer and Pustertaler cattle. Cika cattle should be considered as an authentic and valuable genetic resource, which offers clear opportunities for sustainable agriculture and landscape conservation in marginal and mountain areas.

Introduction

Slovenia is with other Balkan countries located between the Southwest Asian domestication centres and Northwest Europe, where the most productive cattle breeds have been developed. During the agricultural colonization of Europe repetitive founder effects decreased livestock genetic diversity with increasing distance from the domestication centre (Cymbron *et al.* 2005; Ajmone-Marsan *et al.* 2010). Approximately two hundred years ago, homogeneous and genetically isolated breeds emerged with more systematic selection and the standardization of morphology and performance (Felius 1995; Medugorac *et al.* 2009).

Slovenian cattle were described for the first time in 1872 (Schollmayr 1873) as widespread but unnamed, yellow, red, red-brown or brown-black cattle from the Alpine part of the Austro-Hungarian province Carniola (present north-west Slovenia). These cattle were small due to very poor feeding and rearing conditions. In 1878, the brown-red Bohinj cattle in the north-west Slovenian Bohinj valley (Figure 1) had an elegant body frame, light bones, and a relatively high milk production of 1.200 to 1.500 l/year considered a body weight of only 225–280 kg and poor rearing conditions (Hitz 1878). These cattle were kept pure, but were from 1869 also cross-bred with Carinthian Mölltaler sires. The Mölltaler was developed from light-red-pied cattle cross-bred to Pustertaler and Tyrolean Pinzgauer (Felius 1995) and became in 1925 absorbed by the popular Pinzgauer. It had a relatively light body frame (300-400 kg if kept in the mountains), a dark-red coat colour and a high milk production (Felius 1995; Sambraus 1999). In 1894, Tolmin and Bovec cattle from the Soča valley were described as a lighter type of Mölltaler cattle with a high milk production (Povše 1894). There was intensive trading in cattle between different Austro-Hungarian provinces. Bohinj cows were appreciated as milk cows in the Carinthia and Salzburg provinces in Austria (Žan Lotrič 2012), and Bovec cows were sold in the Möll valley.

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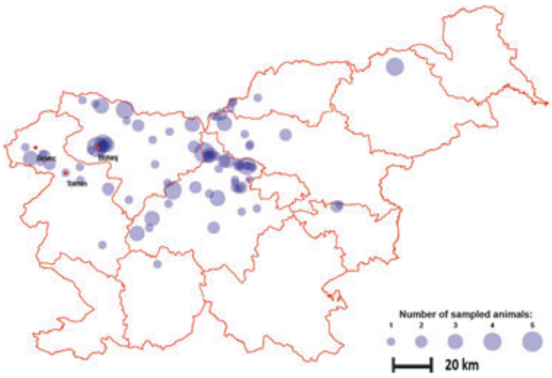

Figure 1 Sampling sites of Slovenian Cika cattle.

Before 1900, improved Bohinj and other local unnamed primitive cattle with Mölltaler sires were named Cika, derived from the ragged demarcation between red basic colour and the white stripe. Cika cattle adopted the red-pied Mölltaler coat colour pattern, but the body frame retained features of the primitive local cattle (Ferčej 1947). Systematic and organized breeding, herd book and milk recording started for Cika cattle in 1906 (Ovsenik 1926).

After 1st World War, the western part of Slovenian territory, where Bovec and Tolmin Cika were kept, became Italian territory and the Carniola province in which primitive Bohinj and Cika cattle were widespread came under Yugoslavian rule. Because import of sires from Austrian Mölltal became expensive, breeders preferred Cika sires. From 1935 to 1940, a number of Austrian Pinzgauer sires were imported to improve body frame and production of the Cika, counting at that time 58 000 heads (Žan Lotrič 2012). During the 2nd World War, the Germans brought in more than 300 original Pinzgauer sires, which were used widely in north-western Slovenian lowlands farms for increasing body size. However, in the mountains, breeders rejected Pinzgauer sires because of calving difficulties and large feed consumption of the offspring. Consequently, two different types of Cika were developed, the large 'lowland' and the light 'mountain or Bohinj' type, respectively (Ferčej 1947).

After 2nd World War, import of larger Pinzgauer sires from Austria became too expensive. In 1952, the Cika population counted 80,000 animals. From 1956 to 1962 breeding shifted to a lighter type of cattle. However, from 1964, Cika were crossed in north-west Slovenia to Simmental and were in West Slovenia replaced with Brown cattle because these breeds should have the less marbled beef, lower fatness, higher milk production, daily gain of the calves and dressing percentage (Žan Lotrič 2012). Only few breeders continued to use the licensed Cika sires for natural service. After 1976, Cika sires were not licensed anymore, and natural services were prohibited by law. Breeders had to choose between the semen of few imported Pinzgauer sires and the semen of crossed Cika sires with only 25–50% of Cika genes (Jeretina 2004). Only later it became known that breeders in the mountains had defied the ban on natural service of unlicensed Cika sires.

In 1992, when autochthonous breeds conservation became popular, breeding experts recorded 59 Cika cattle with known pedigree, most of which were influenced by the Pinzgauer (Jeretina 2004). In 2002, ear tag identification became compulsory, which led to the finding in the mountains of around 300 unregistered original Cika cows that were possibly free from Pinzgauer influence. Because of a lack of breeding records, the similarity of the Pinzgauer and Cika colour pattern and a large variation among animals in conformation traits, Pinzgauer influence could not be excluded. All Cika-like cattle were recorded and divided on the basis of phenotype into three types: Cika type, Semi-Cika type and Pinzgauer type.

Since 2001, breeders are included in the Association of the autochthonous Cika cattle breeders in Slovenia. Since 2005, a breeding programme for Cika cattle was instituted (Žan Lotrič *et al.* 2010). In 2011, the population counted 2558 head with 1115 cows and breeding heifers, mainly located in the northern and western parts of Slovenia.

Original Cika cattle have red coat colour, a typical white lengthwise stripe along the whole back, a ragged demarcation between red and white, white abdomen, chest, udder, and tail, a short red head, rose muzzle, large eyes, well-expressed arcades, short and thin horns with dark points and turned onwards and upwards, a thin skin pleated in the neck and dark hooves. The breeding goal for the cows and sires in the original Cika type suggests less than 125-cm wither height (Žan Lotrič *et al.* 2010). The main breed attributes are early maturity, longevity and resistance, ease of calving, adaptation on poor rearing and feeding conditions, excellent persistency and ability for grazing on the steep mountainous pastures (Simčič 2008) as well as high ratio of lean meat to bones in the carcasses (Simčič *et al.* 2010). During 305 days of lactation, cows produce ca. 3000 kg of milk. Cows are mainly kept in a cow–calf system. The traditional milk and cheese production is still based on mountain dairy farming during the summer (Simčič 2008).

Despite the increasing population size of the Cika cattle in the last 10 years, it is not yet clear whether it should still be considered as an autochthonous breed and how it is related to other European breeds. On the basis of protein polymorphisms (Medugorac *et al.* 1994), Cika from the Pinzgauer-introgressed population were assigned to a 'Balkan – Alpine' cluster with an unstable phylogenetic position. The aim of this study is a broader DNA-based characterization of Cika cattle by an analysis of its genetic variability and relationships to Pinzgauer and other Central European breeds.

Material and Methods

Animals

Blood samples from 93 cows and blood (42) or semen (15) samples from 57 sires were collected in the spring time of 2008 at several farms located in Slovenia (Figure 1). These include semen samples from all Cika sires used in the population. Further we considered breeding area, number of Cika cattle on the farm, age and phenotype and only chose animals unrelated according to pedigree data. The 150 Cika cattle were divided according to phenotype (type traits scores) in Cika type (70), Semi-Cika type (37) and Pinzgauer type (43). DNA was extracted from blood-EDTA samples and from semen employing the DNeasy Blood and Tissue kit (Qiagen). Data from other breeds were contributed by members of the European Cattle Genetic Diversity Consortium (Table 1).

Microsatellites markers

Eighteen microsatellite markers from the Finnzymes' Bovine Genotypes TM Panel 3.1 were amplified in a single multiplex reaction. These include 15 markers (TGLA227, BM2113, TGLA53, ETH10, SPS115, TGLA126, TGLA122, INRA23, BM1818, ETH3, ETH225, BM1824, CSRM60, CSSM66 and ILSTS006) recommended by the FAO (http://dad.fao.org/), from which TGLA53 was excluded because scoring of genotypes was not unambiguous. Allele sizes were standardized using reference DNA (European Cattle Genetic Diversity Consortium. 2006). Standard PCR amplifications were performed in multiplex reactions in 20-μl reaction volumes and analysed on an ABI3130xl Genetic Analyzer (Applied Biosystems). Genotypes were assigned using GeneMapper 4.0 program (Applied Biosystems).

Analysis

Cika cattle were compared either to cattle from Southeast Europe for detection of geographic clines (Figure 2), to breeds that possibly have contributed to the Cika germplasm (Figure 3), or to breeds from surrounding regions for inferring phylogenetic relationship (Figure 4, Lenstra *et al.* 2012). Deviation from Hardy–Weinberg equilibrium (HWE) and locus-by-locus deviations from linkage disequilibrium were detected by the exact test in GENEPOP version 3.4 (Raymond & Rousset 2003). Observed (H_O) and unbiased expected (H_E) heterozygosity as well as the mean number of alleles were calculated using the MICROSATELLITE TOOLKIT (Park 2001). Ancestral components of Cika type, Semi-Cika type, Pinzgauer type were assessed by model-based clustering of genotypes from Cika, and the 6 European reference breeds that were possibly introgressed in Cika (Red Holstein, Limousin, Simmental, Brown Swiss, Pinzgauer, Tux-Zilletaler) using the program STRUCTURE version 2.1 (Pritchard *et al.* 2000) with the admixture model, correlated allele frequencies, a burn-in of 15.000 iterations followed by a 35.000 Markov chain Monte Carlo iterations and assuming seven real populations ($K = 7$, one per breed). Results were visualized in DISTRUCT version 1.1 (Rosenberg 2004). Reynolds genetic distance between three types of Cika cattle, 'Original Cika' (see below) and other Alpine and Balkan breeds were visualized via NeighbourNet graphs using SPLITSTREE version 4.0 (Reynolds *et al.* 1983; Huson & Bryant 2006).

Results

In spite of a reduction in the population size, heterozygosities and number of alleles of the Cika subtypes and Pinzgauer are comparable (Table 2). The Semi-Cika type has the lowest diversity, but the values are still higher than those of other Alpine breeds. Figure 2 shows the geographic diversity pattern in the Alps, Italy and the Balkan with a clear decrease from southeast to north-west and, as already reported by Medugorac *et al.* (2009) the highest diversity in the Balkan Busha breeds.

As alternative of the phenotypic subdivision of Cika, a subset of 66 Cika type or Semi-Cika type samples were selected on the basis of lowest admixture as apparent from model-based clustering (see below). These 'Original Cika' cattle are slightly less diverse than the phenotypic Cika type due to the elimination of admixed animals.

Table 1 Source of microsatellite genotypes from Central European breeds

Country of origin	Breed	N	References
Albania	Illyrian Lowland Busha	30	Medugorac *et al.* (2009)
Albania	Illyrian Mountain Busha	35	Medugorac *et al.* (2009)
Albania	Prespa Cattle	50	Medugorac *et al.* (2011)
Austria	Carinthian Blond	60	Personal communications *
Austria	Ennstaler Bergschecken	41	Personal communications *
Austria	Murbodner	47	Medugorac *et al.* (2009)
Austria	Pinzgauer	40	Personal communications *
Austria	Pustertaler	44	Personal communications *
Austria	Simmental	44	Personal communications *
Austria	Tux-Zillertaler	34	Personal communications *
Austria	Tyrolean Grey	48	Medugorac *et al.* (2009)
Austria	Waldviertel Blond	60	Personal communications *
Bosnia & Herzegovina	Grey Gacko Busha	41	Medugorac *et al.* (2009)
Bosnia & Herzegovina	Bosnian-Herzegovinian Busha	44	Medugorac *et al.* (2011)
Croatia	Istrian cattle	45	European Cattle Genetic Diversity Consortium 2006
Croatia	Croatian Busha	50	Medugorac *et al.* (2011)
Croatia	Slavonian Syrmian Podolian	49	Medugorac *et al.* (2011)
France	Limousin	50	European Cattle Genetic Diversity Consortium 2006
France	Montbéliarde	31	European Cattle Genetic Diversity Consortium (2006)
France	Tarentaise	43	Medugorac *et al.* (2009)
Germany	Original Brawn	25	European Cattle Genetic Diversity Consortium (2006)
Germany	Murnau Werdenfelser	52	European Cattle Genetic Diversity Consortium (2006)
Germany, the Netherlands	Red Holstein (dairy type)	25	European Cattle Genetic Diversity Consortium (2006)
Hungary	Hungarian Grey	60	European Cattle Genetic Diversity Consortium (2006)
Italy	Bruna Italiana	20	European Cattle Genetic Diversity Consortium (2006)
Italy	Cabannina	26	European Cattle Genetic Diversity Consortium (2006)
Italy	Chianina	36	European Cattle Genetic Diversity Consortium (2006)
Italy	Grey Alpine	28	European Cattle Genetic Diversity Consortium (2006)
Italy	Marchigiana	22	European Cattle Genetic Diversity Consortium (2006)
Italy	Maremmana	22	European Cattle Genetic Diversity Consortium (2006)
Italy	Pezzata Rossa Italiana	49	European Cattle Genetic Diversity Consortium (2006)
Italy	Piedmontese	48	European Cattle Genetic Diversity Consortium (2006)
Italy	Rendena	34	European Cattle Genetic Diversity Consortium (2006)
Italy	Romagnola	32	European Cattle Genetic Diversity Consortium (2006)
Kosovo	Red Metohian Busha	27	Medugorac *et al.* (2009)
FYR Macedonia	Macedonian Busha	35	Medugorac *et al.* (2011)
Montenegro	Montenegrin Busha	43	Medugorac *et al.* (2011)
Serbia	Serbian Busha	35	Medugorac *et al.* (2011)
Switzerland	Eringer	50	Schmid *et al.* (1999)
Switzerland	Évolène	15	Schmid *et al.* (1999)
Switzerland	Original Brown Swiss	43	Schmid *et al.* (1999)
Switzerland	Simmental	50	European Cattle Genetic Diversity Consortium (2006)

N, number of animals.
*Baumung and Manatrinon (2007).

To assess introgression of Cika cattle with Pinzgauer or other breeds, genotypes from the three phenotypic types of cattle were analysed by model-based clustering (Figure 3). In addition to Pinzgauer, the Austrian Tux-Zillertaler breed was tested because of its geographic proximity to Cika and similar coat colour pattern. Brown Swiss and Simmental were recommended as breeds for replace Cika in its original breeding area and their semen were used for crossing. Crossing with Limousin and Red Holstein may have taken place for improving carcass quality and milk yield, respectively.

Analysis with $K = 7$ defined six clusters associated with one of reference breeds with only limited crosstalk between the clusters. A seventh cluster is dominant in all three Cika types. This most likely corresponds to the original Cika allele frequencies and suggests that Cika breed has a unique genetic

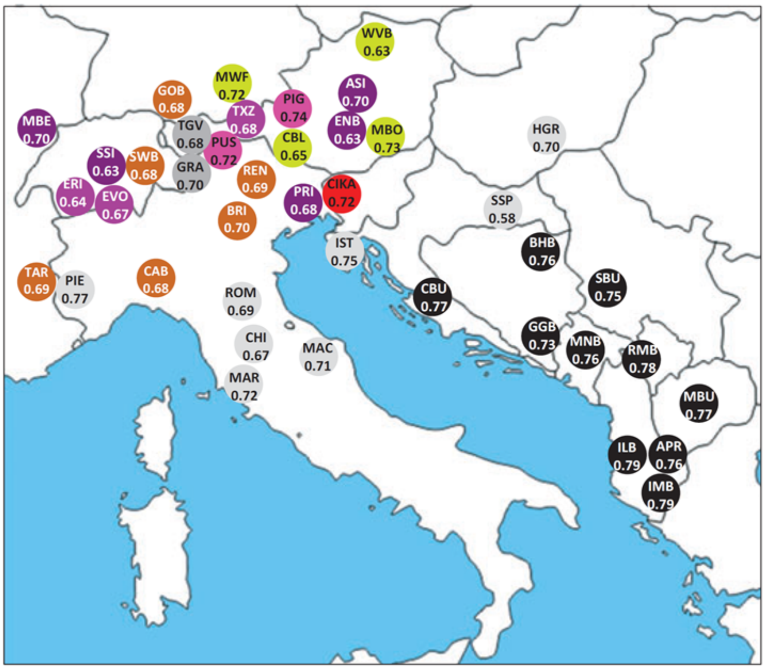

Figure 2 Locations and their expected heterozygosity (HE) of Cika and surrounding breeds. APR, Prespa cattle, ASI, Austrian Simmental, BHB, Bosnian-Herzegovinian Busha, BRI, Bruna Italiana, CAB, Cabanina, CBL, Carinthian Blond, CBU, Croatian Busha, CHI, Chianina, GGB, Grey Gacko Busha, GOB, German Original Brown, GRA, Grey Alpine, ENB, Ennstaler Bergschecken, ERI, Eringer, EVO, Évolène, HGR, Hungarian Grey, ILB, Illyrian Lowland Busha, IMB, Illyrian Mountain Busha, IST, Istrian cattle, MAC, Marchigiana, MAR, Maremmana, MBE, Montbéliarde, MBO, Murboden, MBU, Macedonian Busha, MNB, Montenegrin Busha, MWF, Murnau Werdenfelser, PIE, Piedmontese, PIG, Pinzgauer, PRI, Pezzata Rossa Italiana, PUS, Pustertaler, REN, Rendena, ROM, Romagnola, RMB, Red Metohian Busha, SBU, Serbian Busha, SSI, Swiss Simmental, SSP, Slavonian Syrmian Podolian, SWB, Original Swiss Brown, TAR, Tarentaise, TGV, Tyrolean Grey, TXZ, Tux-Zillertaler, WVB, Waldviertler Blond. The expected heterozygosities on the basis of 14 microsatellites do not differ substantially from estimates based on 30 microsatellites. The colours indicate genetic cluster of breeds (Felius *et al.* 2011): purple, Central Spotted, light-purple, West-Alpine, brown, Central Brown, green, Central-Yellow, pink, East Alpine except Cika, red, Cika, dark grey, Central Grey, light grey, Podolian and Piemontese, black, Balkan.

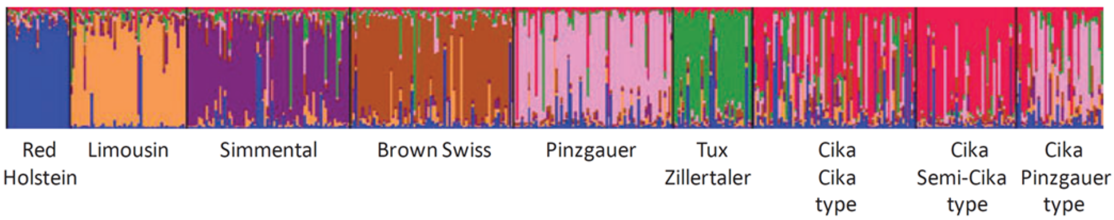

Figure 3 Population partitioning suggested by STRUCTURE.

background. In agreement with the breeding history, there is clear Pinzgauer introgression, most notably in the phenotypic Pinzgauer type (46%), but also in the Cika and Semi-Cika type (14 and 22%, respectively) with hardly any influence of other breeds. Selection of 66 animals with the lowest degree of introgression with this panel of markers resulted in an 'Original' type of Cika cattle with only 5% Pinzgauer introgression.

To infer breed relationships of Cika and surrounding Alpine and Balkan breeds, Reynolds genetic distances (Figure 4a) were visualized in a NeighborNet graph. This indicated several clusters, one of which groups the three types of Cika cattle with Pinzgauer and Pustertaler. The Pinzgauer type of Cika cattle is again intermediate between the Cika type and Pinzgauer breed. The 'Original Cika' cattle (Figure 4b) with minimal Pinzgauer influence still clusters with

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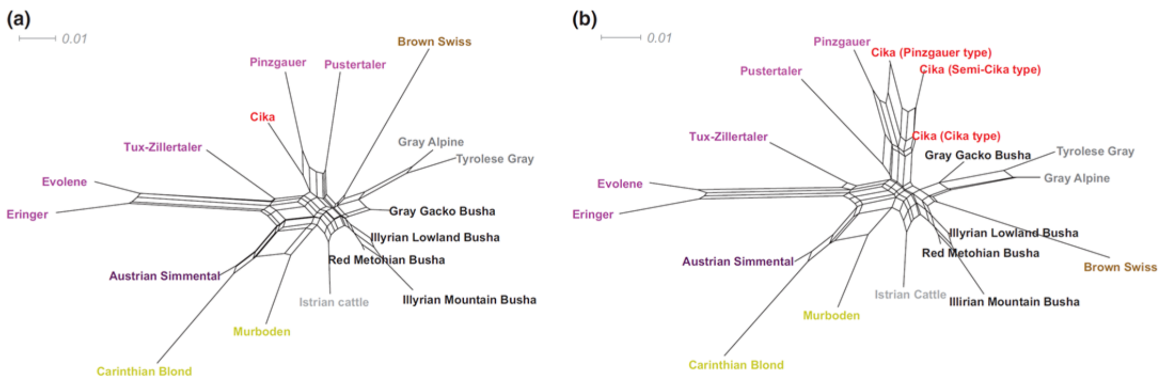

Figure 4 NeighbourNet based on Reynolds genetic distances showing the relationship of (a) the three types of Cika cattle and (b) Original Cika with 16 other European breeds. Colours are as in Figure 2.

Pinzgauer and Pustertaler cattle. This breed cluster is relatively close to a cluster of Tux-Zillertaler, and the Évolène and Eringer breeds from the Swiss canton of Valais.

Also the Busha breeds cluster together, with the exception of the cross-bred Grey Gacko Busha, which is linked to Tyrolean Grey and Italian Grey Alpine. A separate cluster is formed by Simmental and the Austrian Yellow breeds (Carinthian Blond, Murboden), while in agreement with the genetic classification of cattle breeds, the Brown Swiss occupies an independent position (Felius 1995).

Discussion

In spite of becoming almost extinct around 1991, Cika has apparently preserved a relatively high level of genetic diversity, which is comparable with the diversity of Pinzgauer and intermediate between the diversity of other Alpine breeds and the Balkan Busha breeds (Medugorac *et al.* 2009). The high heterozygosity of Pinzgauer type of Cika probably reflects the cross-breeding.

Model-based clustering clearly indicated admixture with Pinzgauer, which is in agreement with the breed history. Cika breeders who inseminated their cows with Pinzgauer semen have now a Pinzgauer cross-bred type of cattle. In contrast, breeders in the mountains have preserved an Original type (66) of Cika cattle, which according to their phenotype belong to either the Cika type (44) or the Semi-Cika type (22).

Our results validate the decision to divide the heterogeneous Cika population in three different types according to phenotype scores when the first breeding programme was started. Phenotypic evaluation detected adequately non-admixed Cika animals with Pinzgauer influence reared in normal rearing conditions, where original Cika has a small body frame despite the enough feed amounts. On the other hand, a few old cows with a sizeable Pinzgauer ancestry (according to the herd book) but with a small body frame because of poor feed conditions were misidentified as Cika type. Phenotypic evaluation also successfully detected Pinzgauer admixture. Introgression of other breeds may be revealed by phenotypic signs as white spots on the head or the legs from Red Holsteins or Simmentals, grey muzzle from Browns or Limousins or yellow claws from Simmentals. However, animal in which cross-breeding (as documented by their pedigree) has not generated any of these signs may be misidentified.

The Original Cika type appears to be well differentiated from 16 nearby European breeds and to constitute a unique genetic resource. As the only authentic and autochthonous cattle breed, it belongs to the Slovenian cultural heritage. It has been adapted to extensive management in the mountains and can contribute in maintaining the Alpine landscape, offering opportunities for sustainable agriculture in marginal areas. These considerations may justify both conservation as well as more detailed genetic and genomic investigations.

Breeding can be targeted towards reducing the Pinzgauer components on the basis of both phenotypic scores and genotypes. Genetic data, preferably with a higher number of markers, would be especially valuable to exclude the possibility that a typical Cika body frame size and morphology reflects environmental factors as poor rearing and feeding conditions rather than its unique genetic background. This approach

Table 2 Number of sampled animals, observed and expected heterozygosity averaged overall 14 loci. Data from Cika cattle are from this study; for the source of data on other breeds, see Table 1.

			Average heterozygosity	
Breed	Sample size	Mean number of alleles	$H_O \pm SD$	$H_E \pm SD$
Cika cattle				
Cika type	70	8.36 ± 2.56	0.701 ± 0.015	0.739 ± 0.022
Semi-Cika type	43	6.92 ± 1.80	0.671 ± 0.020	0.696 ± 0.034
Pinzgauer type	37	7.00 ± 2.04	0.760 ± 0.020	0.740 ± 0.018
'Original' Cika cattle	66	7.50 ± 2.31	0.691 ± 0.016	0.720 ± 0.024
Pinzgauer	40	7.00 ± 1.92	0.743 ± 0.018	0.739 ± 0.020
Pustertaler	44	6.14 ± 1.35	0.731 ± 0.018	0.721 ± 0.023
Tux-Zillertaler	34	6.07 ± 1.49	0.683 ± 0.021	0.681 ± 0.027
Eringer	50	6.64 ± 1.95	0.647 ± 0.018	0.638 ± 0.036
Évolène	15	5.29 ± 1.68	0.667 ± 0.033	0.674 ± 0.036
Austrian Simmental	40	6.36 ± 1.55	0.700 ± 0.019	0.701 ± 0.023
Carinthian Blond	60	6.57 ± 1.50	0.661 ± 0.016	0.647 ± 0.050
Ennstaler Bergschecken	41	5.29 ± 1.38	0.672 ± 0.020	0.629 ± 0.032
Murboden	47	6.29 ± 1.44	0.744 ± 0.017	0.726 ± 0.024
Swiss Brown	43	6.00 ± 1.47	0.669 ± 0.019	0.676 ± 0.024
Tyrolean Grey	48	6.00 ± 2.11	0.677 ± 0.018	0.675 ± 0.033
Grey Alpine	28	6.21 ± 2.08	0.654 ± 0.024	0.704 ± 0.035
Istrian cattle	14	7.86 ± 2.51	0.745 ± 0.017	0.747 ± 0.026
Red Holstein (dairy type)	89	7.93 ± 2.16	0.731 ± 0.013	0.755 ± 0.027
Illyrian Lowland Busha	30	7.57 ± 1.79	0.728 ± 0.022	0.788 ± 0.019
Illyrian Mountain Busha	45	8.14 ± 1.70	0.769 ± 0.017	0.786 ± 0.014
Red Metohian Busha	44	8.92 ± 2.62	0.765 ± 0.017	0.776 ± 0.016
Grey Gacko Busha	41	7.36 ± 1.82	0.702 ± 0.019	0.734 ± 0.026

H_O, observed heterozygosity; H_E, expected heterozygosity; SD, standard deviation.

would also be useful for indigenous Croatian Busha with Alpine influence, again masked by poor rearing conditions (Ramljak *et al.* 2011).

The close breed relationships shown in Figure 4 are consistent with previous literature and breed history. We confirmed the finding of (Edwards *et al.* 2000) that Pustertaler is closely related to Pinzgauer. According to historic sources information (Kaltenegger & Adler 1893), Pustertaler was crossed with Pinzgauer to increase their body size. The close relationship of the Swiss Valais breeds Évolène and Eringer has also been reported previously (Schmid *et al.* 1999). Their close clustering with Tux-Zillertaler is explained by the role of Évolène and Eringer in the development of Tux-Zillertaler breed. The breeds of both clusters also share characteristic short-headed (*brachiocephalicus*) morphology, which was diagnostic in old cattle breed classifications (Felius *et al.* 2011). Likewise, the link of Grey Gacko Busha with Tyrolean Grey and its Italian counterpart Grey Alpine is explained by the use of semen of Tyrolean Grey for improving Busha in Bosnia and Herzegovina (Medugorac *et al.* 1994).

The results presented here are consistent with genetic classification of European cattle (Felius *et al.* 2011), which closely correlates with geography. In fact, these data contributed to this classification by defining an East Alpine breed cluster containing Pinzgauer, Pustertaler and Cika. As shown in Figure 2, Cika conforms to a marked cline of decreasing diversity from the Balkan and Austria to Switzerland and Germany (Medugorac *et al.* 2009). Breeds, not conforming this cline, have either a low diversity because of small population sizes (Ennstaler Bergschecken, Carinthian and Waldviertler Blond, Slavonian Syrmian Podolian) or a high diversity because of multiple admixtures (Piedmontese). In spite of their primitive appearance, the Podolian breeds are about as diverse as the developed Alpine breeds and are clearly less diverse than the authentic Balkan cattle. Although the origin of the Podolian is not clear – descending from Italian Roman period in Italy, but more likely emerged in the Middle Ages on the Podolian steppe (Felius 1995) – the Busha breeds may be the best representative of the primitive taurine cattle from the Neolithic immigration.

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2.3 REŠEVANJE AVTOHTONEGA GENETSKEGA OZADJA V POPULACIJAH S PRIMESMI DRUGIH PASEM Z UPORABO HAPLOTIPOV, FENOTIPOV IN POREKLA – NA PRIMERU CIKASTEGA GOVEDA

Recovery of the native genetic background in admixed population using haplotypes, phenotypes, and pedigree information - using Cika cattle as a case breed

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Izvleček:

Cilj raziskave je bil pridobiti nepristrane ocene parametrov raznolikosti, zgodovino populacije in delež primesi drugih pasem v genomu cikastega goveda. Cika je avtohtona populacija s primesmi drugih pasem, ki ji grozi izumrtje in potrebuje ustrezen program ohranjanja. Genetske analize so bile narejene na genomu na osnovi večjega števila polimorfizmov na posameznem nukleotidu (SNP) Illumina BovineSNP50 čipa pri 76 živalih cikastega goveda in pri 531 živalih iz 14 referenčnih populacij. Za pridobitev nepristranih ocen smo uporabili kratke haplotipe iz štirih označevalcev SNP, namesto posameznega SNP, da bi se izognili ugotovljeni pristranosti BovineSNP50 čipa. Haplotipi so v kombinaciji z nepopolnim poreklom in ocenami lastnosti zunanjosti pokazali potencial za izboljšanje identifikacije čistopasemskih živali z majhnim deležem primesi drugih pasem. Filogenetske analize so pokazale edinstveno genetsko identiteto živali cikastega goveda. Matrika genetskih razdalj »ukoreninjenega drevesa« je pokazala dolgo in široko filogenetsko povezavo med ciko in pincgavcem. Nenadzorovano oblikovanje skupin narejeno z »Admixture« analizo in dvodimenzionalen prikaz genetskih razdalj med posameznimi živalmi sta tudi pokazala, da je cika avtentična pasma, čeprav je po videzu podobna pincgavcu. Živali, ki so identificirane kot najbolj čistopasemske, se lahko uporabljajo kot jedro za reševanje avtohtonega genetskega ozadja v sedanji populaciji s primesmi drugih pasem. Rezultati so pokazali veliko haplotipsko raznolikost lokalno dobro prilagojenih populacij, ki jih rejci niso nikoli intenzivno odbirali in selekcionirali v določeno pasmo. Vse to predlaga način ohranjanja in reševanja, ki se ne opira izključno na iskanje prvotnega avtohtonega genetskega ozadja, ampak predlaga identifikacijo in odstranitev tujih primešanih haplotipov, kar bi zmanjšalo erozijo genetske pestrosti. Uspešna uvedba takšnega načina bi morala temeljiti na združevanju podatkov o fenotipu, poreklu in genomu za proučevano pasmo in za spekter referenčnih pasem, ki so morebiti imele neposreden ali posreden zgodovinski prispevek h genetskemu oblikovanju proučevane pasme.

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RESEARCH ARTICLE

Recovery of Native Genetic Background in Admixed Populations Using Haplotypes, Phenotypes, and Pedigree Information – Using Cika Cattle as a Case Breed

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Abstract

The aim of this study was to obtain unbiased estimates of the diversity parameters, the population history, and the degree of admixture in Cika cattle which represents the local admixed breeds at risk of extinction undergoing challenging conservation programs. Genetic analyses were performed on the genome-wide Single Nucleotide Polymorphism (SNP) Illumina Bovine SNP50 array data of 76 Cika animals and 531 animals from 14 reference populations. To obtain unbiased estimates we used short haplotypes spanning four markers instead of single SNPs to avoid an ascertainment bias of the BovineSNP50 array. Genome-wide haplotypes combined with partial pedigree and type trait classification show the potential to improve identification of purebred animals with a low degree of admixture. Phylogenetic analyses demonstrated unique genetic identity of Cika animals. Genetic distance matrix presented by rooted Neighbour-Net suggested long and broad phylogenetic connection between Cika and Pinzgauer. Unsupervised clustering performed by the admixture analysis and two-dimensional presentation of the genetic distances between individuals also suggest Cika is a distinct breed despite being similar in appearance to Pinzgauer. Animals identified as the most purebred could be used as a nucleus for a recovery of the native genetic background in the current admixed population. The results show that local well-adapted strains, which have never been intensively managed and differentiated into specific breeds, exhibit large haplotype diversity. They suggest a conservation and recovery approach that does not rely exclusively on the search for the original native genetic background but rather on the identification and removal of common introgressed haplotypes would be more powerful. Successful implementation of such an approach should be based on combining phenotype, pedigree, and genome-wide haplotype data of the breed of interest and a spectrum of reference breeds which potentially have had direct or indirect historical contribution to the genetic makeup of the breed of interest.

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Introduction

After domestication in the near east cattle became widespread in Europe along the Danubian and Mediterranean route [1]. During the spread across Europe the populations of cattle experienced the harsh Balkan region, the high Alpine region, and finally reached the middle European lowlands where many modern cattle breeds were developed through selection for high production. The industrial revolution and growth of cities demanded higher efficiency of agriculture. Breeders started to increase and consolidate their herds and consequently first herd books were established in regions with growing demand for food [2]. Natural and artificial selection led to the creation of the first breeds from local populations reared close to these regions. On the other hand, sparsely populated areas far from densely populated cities remained behind with scarcely selected heterogeneous local populations of domestic animals. Progressive growth of global human population, improvement of transport and trade initiated improvement of numerous local populations by importing sires of concurrently well-known breeds. The primary loss of genetic diversity within these species is therefore due to progressive upgrading and replacement of local strains with the imported germplasm of highly selected breeds instead of laborious and slow improvement of local populations based on the local agricultural infrastructure (e.g., [3]). In practice, the accelerated achievements of the short-term breeding objectives are directly related to the genetic homogenization of livestock species and the loss of cultural and traditional values of the respective regions [4,5]. The genetic homogenization of livestock is a special form of biotic homogenization which is considered as one of the most prominent forms of the biotic impoverishment worldwide. This process could even endanger the long-term success of species (populations) that are seemingly the 'winners' in the homogenization process [6].

In this study, the Cika cattle breed was chosen as an example that embodies the processes outlined above. Cika cattle originated from local single-coloured cattle in the region of today's Slovenia. To improve milk yields and body frame breeders were upgrading local cows with more productive Mölltaler sires during the second half of the 19th century [7,8]. The Mölltaler breed was assimilated in the Pinzgauer herd-book in 1925 [9] due to the similar red pied sided coat colour pattern [10], although the Mölltaler breed had a lighter body frame and higher milk production. Thereafter, Pinzgauer sires were used for the continuous upgrading of the Cika breed. After the Second World War upgrading with Pinzgauer was discouraged in favour of displacement crossing with the Simmental (Fleckvieh) breed or replacing with the Braunvieh breed depending on the area and breeding policy [7,8]. This change led to near extinction of the Cika breed. In the meantime, the Pinzgauer population was upgraded with the Red Holstein (RHF) breed on a large scale to improve milk production [9]. This contributed to an indirect gene flow from the RHF also into the Cika population. In 1992, a small number of lowland farms held only about 60 Cika cows admixed with Pinzgauer [11]. These animals were registered in the herd book and had therefore known pedigree. In addition, there were about 300 potentially pure Cika cattle in mountain farms preserved by breeders who preferred natural service with Cika sires but kept no pedigrees. In the last two decades Cika, like other local breeds facing extinction, is gaining popularity and some of these populations are increasing in number due to the higher awareness of farmers about the advantages of their traditional breeds (genetic, cultural and economic) and due to the financial incentives to conserve animal genetic resources.

There are a large number of local domesticated populations of various species worldwide that share commonality with the Cika breed in terms of the processes that shaped their current genetic makeup. Some of them were incorporated into large cosmopolitan populations of currently popular breeds [4]. Some populations, however, exist as separate strains or breeds with various degrees of the admixture. In some cases, breeder associations and governments initiated conservation programs to protect and recover such populations. However, there is considerable discussion about the value and effectiveness of such programs and how such programs should be applied in practice [3].

The aim of this study was to obtain unbiased estimates of the diversity parameters, the population history, and the degree of the admixture in Cika cattle using genome-wide marker data. The Cika breed was taken as a representative of local breeds at risk of extinction and with an unknown degree of the admixture. The genetic analyses presented here are of broad interest due to (i) the known local origin, (ii) the well documented admixture process in one part of the population with deep pedigree records, (iii) the unknown admixture in the other part of the population without pedigree records, and (iv) the availability of type trait classification for the entire population. To assess admixture and diversity parameters 14 reference populations were included. These breeds represented possible sources of both admixture and different levels of artificial selection encompassing highly selected single-purpose dairy breeds, moderately selected dual-purpose Alpine breeds, western neighbors predominantly selected for meat traits, scarcely selected Balkan breeds and one African taurine breed as outlier. To obtain unbiased estimates of diversity parameters short haplotypes were used instead of single SNPs to avoid the ascertainment bias of the BovineSNP50 array. Finally, we discuss a strategy for conservation and revitalisation of Cika and equivalent domestic populations taking into account all the available data.

Materials and Methods

Ethics statement

For samples used in this study no specific permission or ethical approval was required. As specified below we only used already existing DNA from regularly sampled blood and semen samples that had already been used in previous studies. More precisely, DNA samples from the cattle breeds Red Holstein (RHF), Franken Gelbvieh (FGV), German Fleckvieh (DFV), Murnau—Werdenfelser (MWF), Braunvieh (BBV), Original Braunvieh (OBV) and Illyrian Mountain Buša (IMB) were used in number of published studies [3,12,13,14,15]. DNA samples from three Croatian cattle breeds Istrian cattle (HRI), Slavonian—Syrmian Podolic (HRP), Croatian Buša (HRB) were used in two published studies [3,16]. DNA samples from Pinzgauer (API) were used in study published by Ferenčaković et al. [17] and DNA from the case breed, Slovenian Cika (SIC), was used in microsatellite analyses by Simčič et al. [8]. Piedmontese (PMT), Romagnola (RMG) and N'Dama (NDA) genotypes were kindly provided by R.D. Schnabel (University of Missouri, Columbia, USA) and M. Gautier (INRA, CBGP; France). Collection of the original samples was conducted exclusively during regular quality control of the breeding records. These regular quality controls include paternity and identity testing and are organised by the respective breeding associations. Paternity testing involves blood and semen samples. Blood sampling was conducted by veterinarians using approved procedures that avoid unnecessary pain, suffering and damage and which are in accordance with the German Animal Welfare Act. Semen samples were collected by approved commercial artificial insemination stations as part of their regular reproduction and breeding management in the cattle industry. All samples and data analysed in the present study were obtained with the permission of breeders, breeding organizations and researchers. This study did not involve endangered or protected species. Sampling locations of all samples are shown more precisely in Fig 1.

Animals and breeds

Cika cattle are the autochthonous cattle breed in Slovenia with a part of population having evident admixture with the Pinzgauer breed. In 2013, the population size of Cika was 3,097

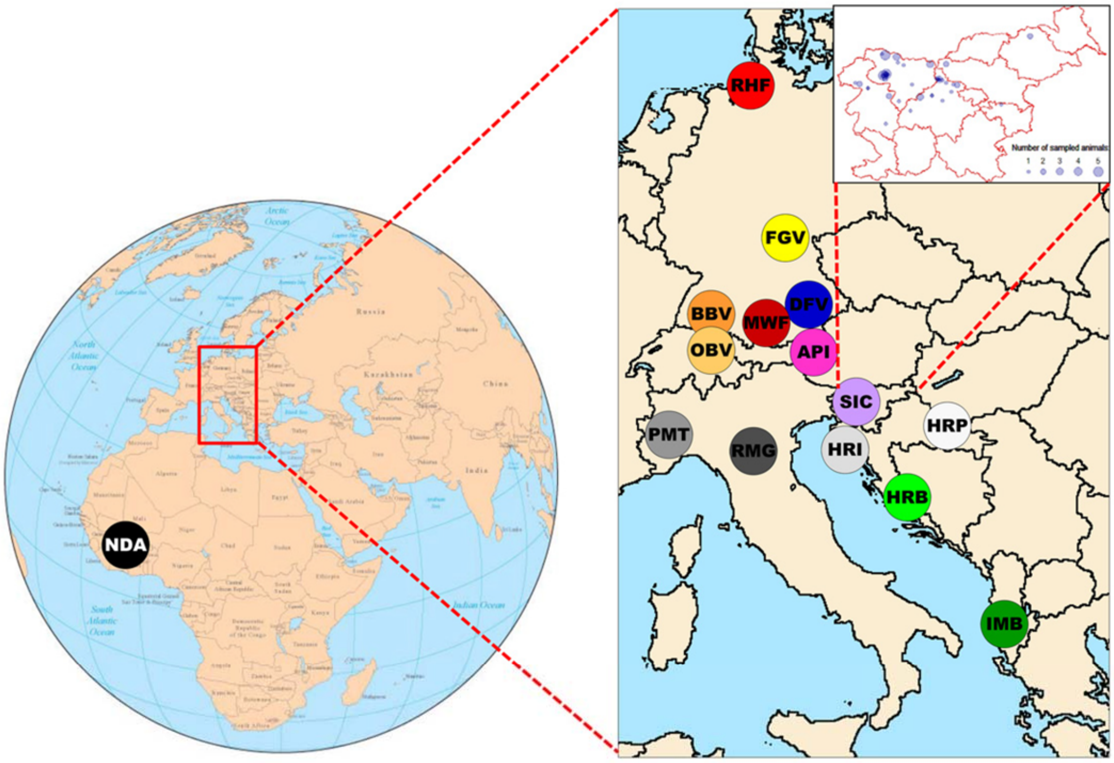

Fig 1. Geographical origin of sampled cattle breeds and more precise sampling locations for Cika within Slovenia. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.

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animals in total with 1,750 cows and breeding heifers. Breeding animals (potentially pure and evidently admixed) are divided into three different types based on the available pedigree information and the type traits classification assigned according to body frame size and other morphological traits, as detailed below.

Blood samples from 38 Cika cows and 16 Cika natural service sires were collected from several farms in Slovenia (Fig 1). To obtain representative sample breeding area, number of Cika cattle on the farm and the age of animals were taken into consideration. Additionally, 22 semen samples of Cika sires used for insemination in the population in recent years were obtained from the insemination centre. Based on the known pedigree data a number of sampled animals were related. The majority of animals (46) were considered as purebred (100%) Cika, 6 animals had less than 12.5% of Pinzgauer contribution, while 24 animals had between 14% and 78% of Pinzgauer contribution. All 76 sampled animals had type trait classification and were grouped in the Cika type (59), Semi-Cika type (6), and Pinzgauer type (11).

To integrate the limited information on the case breed into a broader genetic context, the analysis of genetic variability also included 14 breeds covering an area from the Balkans and Italian Peninsula across the Alps to the North Sea. Additionally, taurine cattle breed N'Dama

Table 1. Sample collection: Breed name and code, breeding purpose, sample size (*N*), origin of the breed and samples.

Breed	Code	Breeding purpose	Origin of breed	Published in	*N*
Red Holstein	RHF	Dairy	Germany	[3,12,13,14]	50
Franken Gelbvieh	FGV	Dairy, beef	Germany	[3,12,13,14]	49
German Fleckvieh	DFV	Dairy, beef	Germany	[3,12,13,14]	50
Murnau—Werdenfelser	MWF	Dairy, beef	Germany	[3,12,13,14]	46
Braunvieh	BBV	Dairy	Germany	[3,12,13,14,15]	50
Original Braunvieh	OBV	Dairy, beef	Germany, Switzerland	[3,12,13,14,15]	35
Pinzgauer	API	Dairy, beef	Austria	[17]	50
Cika	SIC	Dairy, beef	Slovenia	[8]	76
Istrian cattle	HRI	Work, beef, (dairy)	Croatia	[3,16]	30
Slavonian—Syrmian Podolic	HRP	Work, beef	Croatia	[3,16]	24
Piedmontese	PMT	Dairy, beef	Italy	[35,55]	22
Romagnola	RMG	Beef	Italy	[35,55]	21
Croatian Buša	HRB	Dairy, beef, (work)	Croatia	[3,16]	24
Illyrian Mountain Buša	IMB	Dairy, beef, work	Albania	[3,12,13,14]	43
N'Dama	NDA	Dairy, work, beef	Burkina Faso, Guinea, Ivory Coast	[35,55]	37

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(NDA) from Africa (Burkina Faso, Guinea and Ivory Coast) was included as outgroup necessary for some phylogenetic analyses (Table 1, Fig 1). Two Buša (written also as Busha or Buscha) breeds (IMB from Albania and HRB from Croatia) as well as two Podolian breeds from Croatia (HRI and HRP) were considered as southern Cika neighbours. Two Podolian breeds (PMT and RMG) from Italy were considered as western Cika neighbours. Pinzgauer (API) from Austria was used for upgrading the Cika population in the past. Cika and Pinzgauer (API) share similar pied sided coat colour pattern, while the difference in body frame size and some morphological characteristics are evident. Red Holstein (RHF) is included based on its indirect gene flow into the Cika population. Dual-purpose Original Braunvieh (OBV) and Braunvieh upgraded by Brown Swiss (BBV) were suggested as breeds for replacing Cika while German Fleckvieh (DFV) was suggested for displacement crossing of Cika cattle. Additionally, two German dual-purpose breeds, Franken Gelbvieh (FGV) and Murnau-Werdenfelser (MWF), were included as potential indirect historical contributors. Description of the origin of the breeds and the samples, as well as the breeding purpose and number of samples are shown in Table 1. We used pedigree records (RHF, FGV, DFV, MWF, BBV, OBV, API, and SIC) as well as written and oral evidences from the animal owners (HRI, HRP, HRB, and IMB) to sample mostly purebred and unrelated animals.

SNP and haplotype analyses

All 607 animals (Table 1) were genotyped with the Illumina BovineSNP50 BeadChip array using standard procedures (http://www.ilumina.com). Quality control procedures excluded SNPs with genotyping errors (based on available genotypes of relatives), unknown chromosomal position according to the *Bos taurus* genome assembly UMD 3.1 (http://www.cbcb.umd.edu/research/bos_taurus_assembly.shtml#1; autosomal SNPs only), call rate $<95\%$, minor allele frequency <0.025, and the departure from Hardy Weinberg equilibrium within breed ($P<0.01$). Finally, 44,496 autosomal SNPs were considered for the analysis with an average marker density of 56.4 kb.

For haplotype analysis, SNP haplotypes were inferred and missing genotypes were imputed using hidden Markov model of the Beagle software package [18]. Three cohorts were formed, consisting of trios (two parents and one offspring), pairs (one parent and one offspring), and unrelated animals, respectively. Included were also those animals that turned out not to be relevant for this study (7,032 animals in total) but had potential to improve haplotyping accuracy [18]. Genome-wide relationships between individuals were estimated using the method of Powell et al. [19] applied to 44,496 SNP genotypes of 607 animals.

Most phylogenetic analyses were based on a smaller subset of 557 animals since they require representative sample of respective population, where a set of 76 Cika animals was reduced to a set of 26 most unrelated purebred animals and likewise for the other breeds. This selection was based on available pedigree information and genome-wide relationship matrix.

Haplotype diversity

First, the genome was divided into non-overlapping blocks comprised of four SNPs for which the inter-marker distance was less than 50 kb for neighbouring SNPs. We then considered 4,972 blocks as alleles in further analysis. Using short haplotype blocks (maximal length $<$150 kb) as multi-allelic markers enabled the use of various methods developed for biochemical and microsatellite markers over the past decades.

Genetic variability

The number of distinct haplotypes across and within each breed for each 4-SNP-block was counted. These counts and derived allele frequencies were used for the estimation of genetic variability parameters. Initially, a set of 99 random blocks was selected for the purpose of testing using *FSTAT* v.2.9.3 [20]. Identical results from a standard software packages and our own software ensured reliability of the application used here. In the second phase, our validated programs (suitable for larger datasets) were applied on an entire set of 4,972 blocks. The following statistics were collected: the total number of observed alleles (*nA*), mean number of alleles per block (*mA*), number of private alleles (*npA*, i.e., alleles observed in one subpopulation only), number of common alleles (*ncA*, observed in all subpopulations), and rare alleles (*nrA*, i.e., alleles observed in two subpopulations only). This definition of rare alleles largely implies private alleles introgressed from a donor breed into a recipient breed at a lower frequency by crossing. Since the number of distinct haplotypes is influenced by the sample size, we estimated allelic richness (*AR*) [21] too. Furthermore, estimates of genetic variability, observed (H_O) and expected heterozygosity (H_E) [22], as well as *F*-statistics [23] for each block including population pairwise G_{ST} [24,25] were determined. To take into account the concerns about the reliability of classical population differentiation measures like G_{ST} [24,25], we predicted the true population differentiation D_{EST} [25] as the harmonic mean of *D* values across loci using the approach described by Crawford [26].

Cluster analysis

Overall relationships between the breeds were estimated from the D_A distances [27], while the estimation of genetic distances between individuals ($D_{PS} = \ln(PS)$) was based on the proportion of shared alleles, *PS* [28]. A Neighbour network was constructed and plotted with the *SPLITSTREE4* program [29]. A heuristic approach, as described in Veit-Kensch et al. [30], was used to present the individual D_{PS}-distance matrix in the two-dimensional (2D) space. The great deluge algorithm described by Veit-Kensch et al. [30] uses the first two principal components as a starting configuration and further improves it by maximizing the correlation between the multidimensional distance matrix and Euclidean distance matrix of a 2D-plot. This heuristic algorithm aims to organize individuals into groups without prior knowledge of individuals' membership to the predefined breeds or groups. For this reason, the resulting 2D-plot could be seen as a product of unsupervised clustering. This analysis was carried out in a complete set of 607 and in a reduced set of 557 animals. The graphical presentations of 2D-plots of D_{PS}-distance matrix were generated using the R programing language [31].

While above genetic distances and clustering methods rely on short haplotypes, two following clustering methods, *Admixture* and *TreeMix*, are based on SNP genotypes. First, unsupervised clustering was performed on the 44,496 autosomal SNPs in both sets of animals (607 and 557) by the *Admixture* program [32] that adopts the likelihood model implemented in the *Structure* program [33,34] but runs considerably faster. To determine the most likely number of clusters (*K*) in our datasets, we estimated cross-validation error based on 20-fold cross-validation. The best value of *K* exhibited the lowest cross-validation error compared to other *K* values. To improve presentation of the *Admixture* results based on a larger set of Cika animals the input data were sorted by breed proportions estimated from pedigree—from those of 100% pure Cika to those containing up to 78% of Pinzgauer genotype, and likewise for Cika crossbreeds with Red Holstein. The *Admixture* results were presented in a stacked barplot generated using the R programming language [31].

Second, inference of population splits and mixtures based on allele counts of the same set of 44,496 autosomal SNPs and using only design with 557 unrelated animals grouped into 15 breeds was performed by the *TreeMix* program [35]. To set position of the root in the maximum likelihood (ML) tree we define N'Dama, a cattle breed from Africa, as the outgroup population. Furthermore, in two alternative analyses we add one or three migration events in the ML tree, respectively. To account for linkage disequilibrium we used blocks of 100 nearby SNPs in all *TreeMix* analyses.

Results

The average genome-wide relationship coefficient for all 76 Cika animals was -0.013 (± 0.063) with the maximum of 0.68. To create a subset of the most unrelated purebred Cika animals required for phylogenetic analyses we removed highly related animals (relationship coefficient > 0.25), and animals that had exceptionally high relationship coefficient (2 SD above average) compared to the animals from other breeds. Eleven Cika animals were inbred (self-relationship coefficient > 1.05) as well as highly related (> 0.25) to one or more Cika animals. In these pairs the preference was to exclude inbred animals. With the gradual improvement of the pedigree records it became clear that some of these animals are highly admixed. Seventeen Cika animals were misclassified due to the missing or false pedigree data. Among these, 15 were misclassified as pure Cika type but contained 7%-50% API genes and two pure Cika were misclassified as Semi-Cika type. Consequently, at the beginning of the construction of the reduced dataset we excluded 24 admixed animals based on the known pedigree, which contained more than 12.5% of foreign genes. This exclusion was supported by the estimated genome-wide relationships. Furthermore, the analysis of the genome-wide relationship matrix, D_{PS}-distance matrix in the two-dimensional space, and the *Admixture* results between all the remaining animals indicated seven additional Cika animals as related to one or more Alpine breeds (DFV, FGV, OBV and MWF). Even though the background of these relationships in most cases remains unknown we also excluded these animals from the phylogeny analysis and suggest excluding these from the conservation nucleus as well. Combination of all these exclusions led to the final sample of 26 most unrelated purebred Cika animals. The genome-wide relationship coefficient among these 26 Cika animals was on average very low -0.039 (± 0.073) with the maximum of 0.25. This set included only seven genome-wide relationship coefficients over 0.20 (2.2%). Most phylogenetic analyses were based on the reduced subset of 557 animals, i.e., 26 the most unrelated purebred Cika and the similar selection of 531 animals from other

Table 2. Summary statistics—neutral genetic diversity of 15 cattle breeds.

Breed	*N*	*nA*	*mA*	*npA*	*nrA*	H_O	$H_{O[SNP]}$	H_E	*AR*
RHF	50	34474	6.93	465	602	0.709	**0.342**	0.703	6.050
FGV	49	35178	7.08	319	472	0.713	0.334	0.699	6.160
DFV	50	34674	6.97	238	393	0.700	0.326	0.687	6.018
MWF	46	31627	6.36	227	306	0.717	0.334	0.681	5.594
BBV	50	31006	6.24	158	251	0.660	0.307	0.647	5.355
OBV	35	33344	6.71	251	367	0.701	0.325	0.688	6.082
API	50	37987	7.64	451	676	0.716	0.335	0.706	6.493
SIC	26	34807	7.00	237	422	**0.737**	**0.343**	0.718	6.695
HRI	30	36364	7.31	380	603	0.719	0.331	0.711	6.735
HRP	24	26053	5.24	219	299	0.681	0.312	0.642	5.101
PMT	22	36084	7.26	430	526	0.738	0.343	0.721	7.141
RMG	21	30170	6.07	305	368	0.680	0.312	0.667	6.031
HRB	24	**40116**	**8.07**	**664**	**847**	0.702	0.324	**0.746**	**7.771**
IMB	43	**44416**	**8.93**	**1307**	**1467**	**0.743**	**0.344**	**0.748**	**7.620**
NDA		**30135**	**6.06**	**875**	**801**	**0.581**	**0.237**	**0.589**	**5.332**
All	477	58632	11.79	6526	4200	0.699	0.323	0.690	6.279

The sample size (*N*), total number of observed alleles (*nA*), mean number of alleles per haplotype block (*mA* = *nA*/ 4817), number of private alleles (*npA*), number of rare alleles defined as alleles observed in only two subpopulations (*nrA*), average observed heterozygosity (H_O), H_O estimated from SNP genotypes ($H_{O[SNP]}$), average expected heterozygosity (H_E) and allelic richness (*AR*[21]). RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG—Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.

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14 comparison breeds. On the other hand, all 76 purebred and admixed Cika animals were included in the larger dataset of 607 animals, which was used for the 2D presentation and the ADMIXTURE analyses. Throughout the remainder of the text, when dataset is not explicitly mentioned the smaller set is implied.

Genetic diversity

The number of the common alleles (*ncA*) was 11,231 with 2.26 per haplotype block on average. The *nA*, *mA*, *npA*, H_O, $H_{O[SNP]}$, H_E, and *AR* of Cika in comparison with the other 14 breeds are shown in Table 2. The total number of observed alleles (*nA*) and the mean number of alleles (*mA*) per haplotype block ranged from 26,053 and 5.24 in HRP to 44,416 and 8.93 in IMB, respectively, while Cika (*nA* = 34,807; *mA* = 7.00) was in the middle of these extremes. Cika also showed lower *nA* and *mA* compared to API (*nA* = 37,987; *mA* = 7.64). IMB showed the highest number of private (*npA* = 1,307) and rare alleles (*nrA* = 1,467) while BBV had the lowest values (*npA* = 158, *nrA* = 251). The discrepancy between these two extremes is enormous, i.e., the number of private and rare alleles in the highly selected BBV breed is 8.27 and 5.84 times lower, respectively. The second Buša breed (HRB) showed lower but still very high *npA* (875) and *nrA* (801). However, Cika showed the largest difference between *npA* (237) and *nrA* (422). Among all 15 breeds only in two Bušas (HRB and IMB) and N'Dama were H_O lower than H_E. Only IMB (0.743) and PMT (0.738) showed higher H_O compared to Cika (0.737). Allelic richness, a diversity measure not influenced by sample size, was the highest in HRB (7.771) and the lowest in HRP (5.101). Cika had allelic richness (6.695) similar to API (6.492), HRI (6.735) and PMT (7.141), which are the three geographically closest breeds. Allelic richness showed highest correlation with *mA* (0.90) and H_E (0.88) but lowest with $H_{O[SNP]}$ (0.53).

Table 3. Pair-wise population differentiations.

	RHF	FGV	DFV	MWF	BBV	OBV	API	SIC	HRI	HRP	PMT	RMG	HRB	IMB	NDA	$\bar{D}_{EST}$
RHF		0.166	0.185	0.190	0.220	0.174	0.153	0.134	0.162	0.241	0.120	0.199	0.103	0.119	0.318	0.177
FGV	0.087		0.077	0.129	0.161	0.109	0.112	0.074	0.117	0.207	0.065	0.156	0.061	0.087	0.273	0.128
DFV	0.097	0.051		0.125	0.157	0.107	0.119	0.061	0.123	0.213	0.070	0.166	0.065	0.100	0.278	0.132
MWF	0.100	0.074	0.075		0.167	0.122	0.134	0.104	0.137	0.223	0.092	0.177	0.084	0.111	0.282	0.148
BBV	0.122	0.098	0.099	0.104		0.114	0.167	0.135	0.163	0.253	0.124	0.200	0.121	0.147	0.312	0.174
OBV	0.093	0.066	0.067	0.073	0.078		0.115	0.081	0.109	0.205	0.068	0.153	0.058	0.086	0.267	0.126
API	0.080	0.065	0.069	0.075	0.099	0.069		0.046	0.109	0.199	0.065	0.150	0.055	0.076	0.266	0.126
SIC	0.071	0.047	0.043	0.061	0.082	0.052	0.033		0.078	0.174	0.033	0.122	0.022	0.045	0.243	0.097
HRI	0.082	0.065	0.069	0.076	0.095	0.064	0.062	0.047		0.166	0.061	0.102	0.043	0.061	0.240	0.119
HRP	0.131	0.118	0.124	0.128	0.152	0.120	0.113	0.099	0.096		0.160	0.210	0.137	0.153	0.293	0.202
PMT	0.065	0.043	0.047	0.056	0.077	0.047	0.042	0.028	0.041	0.093		0.099	0.012	0.024	0.227	0.087
RMG	0.108	0.092	0.099	0.103	0.124	0.094	0.088	0.074	0.065	0.126	0.065		0.086	0.102	0.256	0.155
HRB	0.055	0.037	0.041	0.048	0.070	0.039	0.035	0.019	0.029	0.077	0.015	0.054		0.008	0.204	0.076
IMB	0.060	0.048	0.055	0.059	0.081	0.050	0.044	0.030	0.036	0.084	0.022	0.060	0.010		0.219	0.095
NDA	0.179	0.163	0.170	0.172	0.197	0.165	0.158	0.145	0.145	0.190	0.138	0.167	0.120	0.125		0.263
$\bar{G}_{ST}$	0.095	0.075	0.079	0.086	0.105	0.077	0.074	0.059	0.069	0.118	0.056	0.094	0.046	0.054	0.160	

D_{EST} values as an estimator of true differentiation [24] among 15 breeds are presented above the diagonal and pair-wise G_{ST} below the diagonal. Average values ($\bar{D}_{EST}$ and $\bar{G}_{ST}$) are presented in the last column and row. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama

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Clustering analyses

Pairwise population differentiations are shown as D_{EST} and G_{ST} values in Table 3. The correlation between D_{EST} and G_{ST} was very high (0.990) but D_{EST} showed better diversification (from 0.008 to 0.318). The highest average D_{EST} values were observed among NDA from Africa, autochthonous HRP and highly selected RHF as well as BBV when compared with other breeds (0.174–0.263). The lowest average genetic differentiations were observed for Bušas, PMT and Cika when compared with other breeds (0.076–0.097). Pairwise D_{EST} value between Cika and API (0.046) was similar to the one between Cika and IMB (0.045) as well as between API and HRB (0.055). The lowest D_{EST} value when comparing Cika with other breeds was between Cika and HRB (0.022) followed by Cika and PMT (0.033) differentiation. The lowest D_{EST} when comparing all breeds was between HRB and IMB (0.008), which demonstrates the low genetic differentiation of Buša.

Nei's D_A-distances were plotted as a Neighbour-Net (Fig 2) rooted by NDA population. The taurine outgroup from West Africa joined the network of the European cattle breeds at group of three Podolian breeds (HRI, HRP, RMG). The fourth Podolian breed PMT with relatively high allelic diversity ($AR = 7.141$) doesn't show clear clustering in this design and has a higher genetic similarity to Alpine breeds. The Neighbour-Net graph suggested relatively long-term and close co-evolution of both Braunvieh populations (OBV and BBV). Similarly close but shorter co-evolution is suggested for DFV and FGV. On the contrary, Cika and Pinzgauer showed relatively long but wide phylogenetic connection (Fig 2). Both branches were similarly long. The Cika-Pinzgauer cluster was flanked by RHF with its relatively long branch on the one hand, and by the FGV-DFV cluster on the other. Both Buša breeds, HRB and IMB, were easy to recognise due to their short branches. They were clustered together, but split from each other just after the tree trunk. The longest branches belonged to the HRP and NDA.

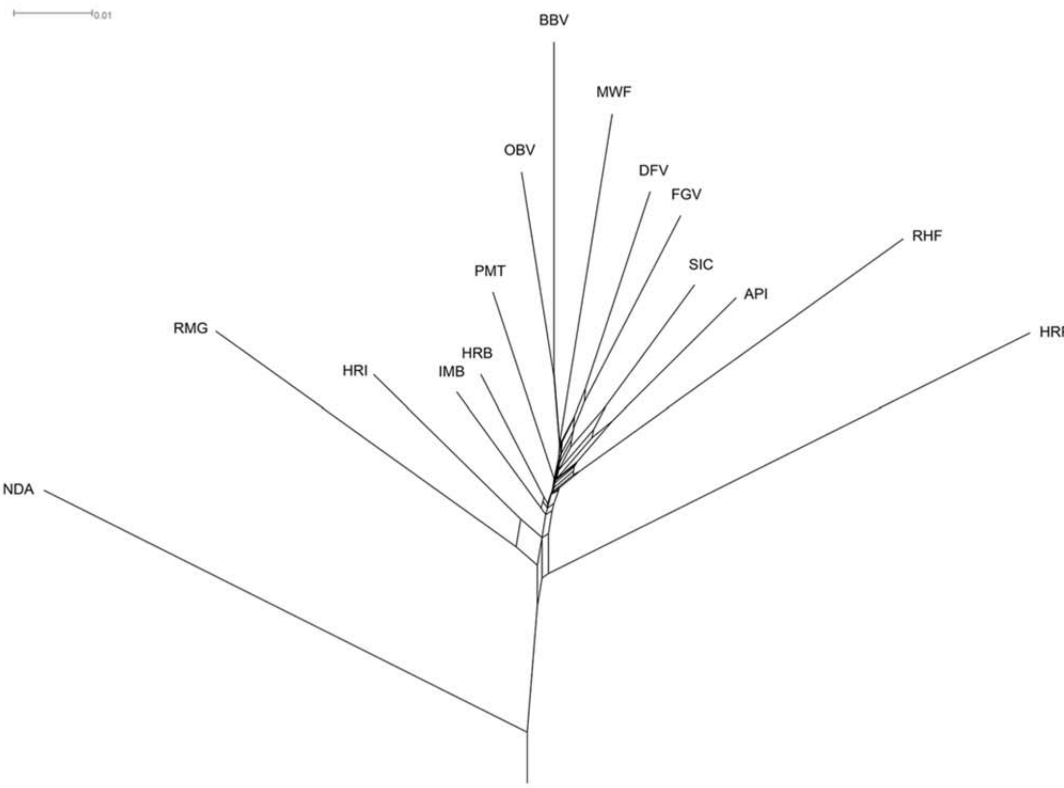

Fig 2. Presentation of Nei's *DA*-distance matrix as a rooted Neighbour-Net graph. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.

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Additional to the above mentioned phylogenetic analysis, we inferred patterns of splitting and possible historical mixing between investigated populations with maximum likelihood (ML) methods implemented in the *TreeMix* program. The ML tree, rooted by N'Dama population (S1 Fig), shows highly similar characteristics to the above described Neighbour-Net. Assuming one migration event, we detect relatively recent migration of DFV genes into the Cika breed while remaining structure of tree stays unchanged (S1 Fig). This result is consistent over series of five independent *TreeMix* runs. Assuming two and three migration events leads to inconsistent results over five independent *TreeMix* runs (S1 Fig). Most common feature of these inconsistent runs is suggested migration of early N'Dama-ancestors to the root of the South-East European cattle populations (IMB, HRB and HRP) or to HRB only. Next common feature is suggested migration of PMT ancestors to the root of the HRI-RMG cluster (S1 Fig).

Fig 3 shows the D_{PS} distances in the two dimensional presentation (2D). The distribution of the larger set with 607 individuals of 15 breeds is shown in Fig 3a, where Cika population was represented by 76 pure and admixed individuals. Thirteen breeds formed well-recognized clusters and were clearly separated from each other, while Cika and HRB animals were scattered to

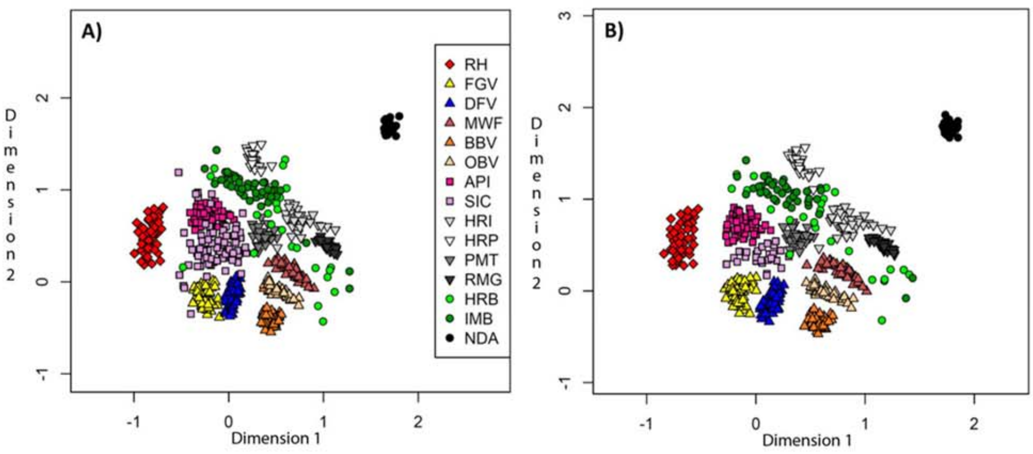

Fig 3. Individual D_{PS}-distance matrix in the two-dimensional space. A dataset with all 76 Cika animals **(a)** and a reduced dataset with 26 animals **(b)**. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.

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a large extent. Most HRB individuals were scattered close to the IMB and HRI clusters, while others seemed to be outliers. Cika clustered in the neighbourhood of API with few individuals falling into the API cluster. Some Cika individuals also seemed to be outliers. Fig 3b shows the distribution of the reduced set, where Cika is represented by 26 purebred individuals that were less inbred and were nominally unrelated. Analysis of this data led to the formation of 14 distinct clusters. Pure Cika individuals were clustered independently from the API cluster though in the neighbourhood of the API cluster. Only HRB showed a lot of outliers just like in the Fig 3a and did not form its own cluster.

The results of the *Admixture* analysis of the reduced set detected the lowest cross-validation error at $K = 13$. Fig 4 and S2 Fig presents the *Admixture* results for this K value in the larger set with 76 Cika animals (Fig 4a) and in the reduced set with 26 Cika animals (Fig 4b). Fourteen breeds created their own clusters and these results suggested that HRB is a synthetic population (Fig 4). In Fig 4a admixture is clearly seen with the API (26%), DFV (9%), Brown breeds (3%),

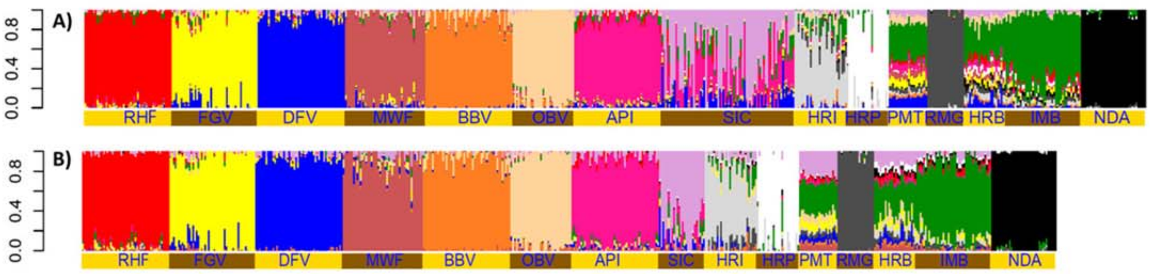

Fig 4. The *Admixture* analyses of two data sets. A dataset with all 76 Cika animals **(a)** and a reduced dataset with 26 animals **(b)**. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.

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and RHF (2%). Contribution from the Cika's southern neighbours (HRI-IMB 8%) was also indicated. However, when we considered the reduced set (Fig 4b) the admixture proportions in Cika animals were evidently lower though still present (API 9%, DFV 6%, OBV-BBV 2% and HRI-IMB 5%).

Correlations between genetic, pedigree and phenotypic parameters

The correlation between type trait classification and the pedigree contributions from Pinzgauer was 0.71 (S1 Table). Likewise, the correlation between type trait classification and the average genome-wide relationship between each Cika animal to all sampled Pinzgauer animals was 0.65, while the correlation between the pedigree contributions from Pinzgauer and average genome-wide relationship coefficient between each Cika animal to all included Pinzgauer animals was nominally higher (0.69). The correlation between type trait classification and the proportion of admixed Pinzgauer genes within Cika individuals from the *ADMIXTURE* analysis was 0.64, while the correlation between type trait classification and the proportion of Cika genes from the *ADMIXTURE* analysis was 0.53.

S3 Fig shows the D_{PS} distances in the two dimensional presentation (2D). The dataset included Cika and four breeds (RHF, FGV, DFV and API) with possible direct contribution to the Cika gene pool as identified by genome-wide IBS and IBD matrix. In the three parts of the S3 Fig we highlighted animals selected as pure Cika based on a) combined haplotype, pedigree data and type trait classification, b) pedigree information alone and c) type trait classification alone. The comparison of these figures reveals the subtle differences between separate and combined approach for selection of conservation-worthy animals. Type traits and pedigree information used separately identify Cika animals with API contribution correctly. Only one of 14 animals with significant API contribution was misallocated to pure Cika by type traits classification (S3 Fig). On the other hand, both pedigree information and type traits wrongly placed seven animals with significant contribution of foreign breeds other than API (i.e. DFV, FGV or RHF). Furthermore, combined approach as well as type traits alone classified 13 Cika animals as worth conserving even if the written herd-book records suggested some contribution of API breed. Likewise, two additional animals were classified as pure Cika in spite of type trait classification as Semi-Cika. In total, 54 (71%) of 76 investigated animals were classified as pure Cika by combined approach. Only two third of these (37) would be allocated to pure Cikas by herd-book records or type traits alone.

Discussion

Cika cattle, like many other local breeds, was under pressure with the introduction of cosmopolitan breeds and was near extinction due to the continuous upgrading with Pinzgauer as well as crossing with Fleckvieh and replacement with Braunvieh. When Cika population was included in the conservation program, doubts have been raised about the uniqueness of the breed and the level of the admixture. The Cika herd book had records on mostly admixed animals with known pedigree going back a number of generations and with relatively accurate estimated proportions of foreign genes from Pinzgauer and Red Holstein. In 2002, potentially pure Cika animals from the mountain area were included in the program as 100% pure Cika based only on type traits classification even though their pedigree was unknown. However, this increased population size but also doubts in the breeding community about the uniqueness of the population.

These conditions partly resemble a curious situation that arose from the restoration and conservation of the Austrian Murbodner (AMB) cattle breed [12]. Original Murbodner cattle were gradually upgraded by Franken Gelbvieh and/or replaced with Fleckvieh after the Second World War. At the beginning of 1980s, some Austrian organisations started to search for the typical AMB animals preferably without the Gelbvieh genes. Since the most typical AMB candidates with extensive pedigrees had one or more Gelbvieh ancestors the selected putative purebred AMB animals predominantly did not have pedigree records. Because both AMB and Gelbvieh show morphological similarity, it was not possible to effectively exclude Gelbvieh admixture in these animals based on the phenotype alone. Recently, phylogenetic results showed large admixture of Gelbvieh genes in the restored AMB population [12]. Despite the current conservation program of AMB as a putative autochthonous cattle breed, in fact it appears nowadays as a subpopulation of Gelbvieh that is also endangered. This demonstrates that upgrading and subsequent selection on the introgressed genes could result in the loss of genetic identity of a specific breed, even if considerable efforts were made to find the original purebred animals. One of the goals of this study was to capitalize on the recent advent of high-throughput genotyping techniques to check if a comparable scenario is probable for Cika and Pinzgauer. With the power of high-throughput data providing accurate genetic structure of the subpopulations [36] and knowledge of actual individual relationships derived from more than 40,000 SNP markers [37], it should be ensured that an appropriate conservation program is in place for Cika.

In order to achieve these conservation goals and to avoid the ascertainment bias of the BovineSNP50 array we used the results based on the 4-SNP-block haplotypes. The BovineSNP50 array was developed mainly on the SNP allele frequency spectrum of highly selected, commercial, and cosmopolitan breeds [38]. Estimates of genetic diversity can therefore be influenced by the ascertainment bias of the array and can even lead to incorrect conclusions [36, 38–41]. On the other hand, haplotype diversity is robust to the marker ascertainment bias and provides more information regarding diversity and population history as shown through simulations and empirical data [42–44]. In spite of this, most currently published studies on cattle diversity are based on the BovineSNP50 genotype data instead of the haplotype data. One exception is the phylogenomic study of ruminants by Decker et al. [41]. Likewise, Amador et al. [45] used haplotypes of 10 consecutive SNPs from the OvineSNP50 BeadChip. The comparisons of diversity parameters or phylogeny based on the SNP allele frequency and the short haplotypes were of secondary interest of this study, but we would like to point out to the difference in the observed heterozygosity (Table 2). Based on haplotypes the highest H_O was obtained for IMB (0.743), while H_O estimated from the SNP genotypes ($H_{O[SNP]}$) was comparably high in RHF, SIC, PMT and IMB (0.342–0.344). The high $H_{O[SNP]}$ estimated in RHF sample is in conflict with a relatively low haplotype diversity and could be due to the ascertainment bias. Supporting this result is also the low correlation (0.53) between haplotype allelic richness and $H_{O[SNP]}$ (Table 2). In order to avoid the ascertainment bias, only results based on the 4-SNP-block haplotypes are discussed below.

Considering the situation that arose when restoring the AMB, the main idea was to combine all of the available data to identify admixed animals which were recorded as purebred Cika based only on type traits classification after their discovery in 2002. In addition, animals with known pedigree can be misclassified due to the errors in the pedigree or the discrepancy between the expected and the actual admixture. With the exclusion of the admixed and highly related Cika animals we wanted to show the phylogenetic characteristic of the original (pure) Cika only as well as to build a knowledge base for later practical conservation work on similar populations. Ability of the methods implemented in the ADMIXTURE and comparable programs to allocate foreign genome and haplotypes to their respective breed depends on the study design. Our experience suggests that in cases where pedigree is not known, a feasible way to find unknown genetic admixture is to add all possible direct and indirect source populations to the initial dataset. Similar to other endangered breeds with comparable history there is no perfect design and it is likely that the dataset used in this study does not include all breeds from which genes could have been admixed in Cika, e.g. the already extinct Mölltaler breed.

Cika and HRB animals, which were identified as highly inbred by the genome-wide IBD matrix, were outliers in the 2D space, far away from their breed clusters (Fig 3a).These outliers are present in the population of Cika and HRB due to the population fragmentation [16]. Breeders in the marginal mountain areas that prefer local breeds used their own natural service bulls. These bulls were usually related to the dams, which led to inbreeding. This could be a common situation in endangered indigenous breeds under low management level. Cika animals identified as highly inbred were also detected as highly related to one or more other animals in our design. In such a situation we preferred to exclude inbred animal from the set for phylogenetic analyses but not from a conservation program.

According to the expected and observed haplotype heterozygosity, Balkan breeds were more diverse than Alpine breeds and dual-purpose breeds were more diverse than highly selected single-purpose breeds. Large current and past effective population size as well as virtual absence of systematic artificial selection combined with proximity to major centres of domestication in the Fertile Crescent could be main reasons for higher diversity in Buša strains [12,14]. Even if there are no historical records for ancient or recent introgression of *indicine* or African *taurine* ancestry into Balkan cattle breeds (Buša or Podolic) this possibility exists. Furthermore, Balkan cattle population is located closer to current Anatolian cattle that carried both *indicine* and African *taurine* ancestry [46] which could indirectly shape the distribution of rare and private alleles in cattle population of Balkan. If so, we would expect systematic effect in all indigenous Balkan cattle breeds, i.e. increased allelic diversity in both Buša and Podolic cattle. On the contrary, two Balkan breeds (IMB and HRP) are at the opposite ends for allelic diversity according to our results. However, some results of the *TreeMix* procedure support results of [46] and suggest possible migration of earlier N'Dama-ancestors to the root of the South-East European cattle populations (IMB, HRB and HRP). This migration edge added basal to phylogeny, i.e. close to root, indicates that possible admixture occurred very early in time or even from a more diverged population ancestral to both South-East European and African taurine cattle. Be that as it may, the main objective of this study is to verify known admixture in the case breed Cika which was confirmed by *TreeMix* analyses. In addition to the close relationship between Cika and API, *TreeMix* suggests relatively recent mixture with DFV. This could explain higher genetic diversity of current Cika population. On average, the neutral diversity estimators put Cika in the position between the Balkan breeds (Buša and Podolic) and the Alpine breeds, which corresponds with the geographical location of Slovenia as well as with admixed status of Cika.

The high average D_{EST} values observed between RHF and other breeds ($\bar{D}_{EST}$ = 0.177; Table 3) may reflect artificial selection, while the high $\bar{D}_{EST}$ value for HRP ($\bar{D}_{EST}$ = 0.202) could reflect long-term isolation of the breed and a limited number of founders after the bottleneck [16]. Cika showed the lowest pairwise D_{EST} values with HRB (0.022) and PMT (0.033) despite remarkably different breed characteristics (e.g., in horns, coat, and mucosa colour). Furthermore, D_{EST} value to Buša strain from Albania (0.045) is also lower then to Austrian Pinzgauer (0.046) despite relatively long geographical distance. These low D_{EST} values to both Buša strains and PMT suggest either low genetic differentiation of all four subpopulations or ancient genetic relationships through past trades which is possible given the geographical proximity. The lowest $\bar{D}_{EST}$ values for HRB (0.076), PMT (0.087), IMB (0.095) and SIC (0.097), the broad allelic diversity in all four breeds (Table 2) and the clustering by *Admixture* suggest low differentiation as being more relevant. Despite the verifiable evidence of the direct introgression from Pinzgauer to Cika, it should be considered that the D_{EST} matrices were prepared with only potentially pure Cika animals. These animals show relatively low genetic differentiation to Pinzgauer (D_{EST} = 0.046). The key question is which part of relatively high genetic diversity in Cika is caused by admixture and which part represents original neutral diversity of the population under relatively low artificial selection.

Allelic diversity represented by *nA*, *mA*, *npA*, *nrA*, and *AR* (Table 2) clearly suggests two artificially unselected Buša strains as the populations with the highest neutral diversity. On the other hand, one Podolic breed (HRP, weak artificial selection but with known recent population bottleneck, [16]) and one highly selected Alpine breed (BBV, with small effective population size [14]) demonstrated the lowest allelic diversity. Cika shows a low number of private alleles but relatively high H_O and *AR*. Comparing *nrA* and *npA* Cika show highest proportion of rare alleles, defined as alleles observed in only two subpopulations (*nrA*/*npA* = 1.78). This is due to sharing of 24% rare allele with API, i.e., otherwise private alleles of API or SIC were classified as rare due to sharing. Taken together, these patterns suggest that even the sample of 26 most pure Cika is still partly admixed. Then again, unsupervised clustering performed by *ADMIXTURE* and 2D presentation of D_{PS}-distances identified Cika as a breed worth preserving. Even though there are recognisable proportions of Alpine (mainly API and DFV) and southern (IMB, HRI) contributions in most Cika animals, both unsupervised approaches identified Cika as a population with a unique genetic identity. Comparison of the clustering based on the initial set of 76 Cika animals (Fig 3a and Fig 4a) with the results based on 26 selected Cika animals clearly suggest that the multistage procedure used here is able to detect individuals which are more important to preserve. It is important to keep in mind that additional animals, considered as less admixed, were not included in the set of 26 Cika animals due to their high relationship to one or more animals already included in the set. All these currently living, less admixed animals should be considered as Cika nucleus for breeding of sires and bull dams of the next generations and thus recovering the native genetic background of Slovenian Cika. Different de-introgression strategies were developed based on the pedigree information [47], molecular information [45,48,49], or other traits, like breed specific phenotypes as well as productive traits [50]. A combination and improvement of these approaches should be considered for de-introgression of admixed endangered domestic populations. The S1 Fig illustrates advantages of combined approach to the separate usage of pedigree or phenotype information. Practical conservation breeding should inevitably combine all available information but be aware of the ascertainment bias of the most SNP arrays developed for the livestock species. This is especially important if the breed of interest was not involved in the development of the SNP array. Previously published simulation studies [48,49] did not consider this bias. Local breeds like Cika were not considered when Bovine SNP array was designed [38] and consequently their private alleles are not known and not included onto array causing the markers to be on average more informative for the considered popular commercial breeds. On the other hand, Cika and other endangered breeds are facing extinction due to the introgression and replacement by the commercial breeds that contribute their most informative markers onto SNP arrays. Therefore, de-introgression strategies using information on private alleles [48] is currently only of theoretical interest or useful only for the breeds included in the creation of a SNP array, which are mostly not at risk of extinction. Also, the use of breed specific phenotypes (i.e. private phenotypes) for de-introgression [50] will result, at most, in the recovery of certain regions in genome linked to them. For example, there is a large discrepancy between phenotypic and background genetic differentiation of geographically close cattle breeds Blanc-Bleu Belge and Holstein [12,14]. As mentioned before, Austrian Murbodner breeders used a combination of phenotypes and pedigree records to recover the breed, but according to the molecular genetic results the success of recovery following this approach was limited [12]. Our case breed is also extensively phenotyped and breeders are more familiar with using phenotype than haplotype data. However, phenotype information alone is not conclusive though it is important to preserve some essential breed characteristics. Our experiences (S1 Fig) suggest combined use of all the available information with an emphasis on molecular information. In summary, it can be concluded that pedigree data as well as type traits classification identified quite well the animals admixed with the main breed (here API) used for upgrading. Animals with significant proportion of gene introgressed by historical or unexpected crossing (e.g. OBV, BBV, DFV, FGV, RHF) were not identified by pedigree data and/or type traits. Erroneous or incomplete pedigree records lead to misclassification in both directions. For illustration, in this study ten Cika animals were scored as admixed by genealogical coancestry despite being pure according to molecular coancestry. Detailed investigation of affected cases suggests wrong pedigree arising from the use of Cika bull for natural mating after official insemination by API sire was not successful. Additionally, we recognized the risk of misclassification of some purebred animals kept in well controlled environment as Semi-Cika. This is due to the subjective expectation of the assessor that pure indigenous animal should be smaller sized or with lower production then observed. These biased expectations present a common threat at phenotypic evaluation of endangered, indigenous, domestic populations. Making such mistakes leads to double losses, i.e. we lose preferential indigenous variants able to compete with common commercial breeds.

Combined use of all the available information with an emphasis on molecular information should bear on haplotypes, short or long, depending on the characteristics of introgression events. The successful identification and the removal of exogenous haplotypes present in an admixed population will depend on the availability of high quality haplotypes of case and source populations. In this case study we detected admixed and not related animals with large exogenous haplotypes at different chromosomes (data not shown). Appropriate inclusion of progenies from these individuals (via regular or target mating) into the nucleus could effectively remove exogenous haplotypes and avoid increase in inbreeding. Likewise missing and wrong information in the incomplete pedigree records could be efficiently improved and corrected based on the molecular composition of a breed. Generally, the advantage of using molecular information increased with the increase in SNP density. In scenarios evaluated by [51] the SNP density should reach at least 3 times the effective population size per Morgan or about 500 SNPs/Morgan. As repeatedly confirmed larger reference panels and high marker density substantially increase haplotype quality and imputation accuracy, particularly for low-frequency variants [18]. Therefore, unconsolidated indigenous breeds with large population size whose private or rare alleles were not involved in the development of the SNP array need even higher SNP density to permit high quality haplotyping. Many livestock breeds under the pressure or even under the threat of extinction are indigenous local strains structured in more diffuse subpopulations, like Pramenka sheep [52] or Buša cattle [3]. Such populations are characterised by a low breeding level in the past, resulting in high neutral diversity and a large effective population size [3]. On the contrary, exogenous haplotypes come from relatively compact and administratively isolated commercial populations. Therefore, the de-introgression of these loosely defined and before admixture highly diverse populations should rely less on the search for the original genetic background of a native population but rather on the identification and removal of haplotypes from exogenous compact common breeds. Our case population shows most of these characteristics and is a suitable candidate for the implementation of the conservation and recovery approach, combining all the available phenotype, pedigree, and high-density haplotype information. Successful de-introgression process will, however, be influenced by the differentiation among the target population and populations they have admixed with. The higher the similarity, the more difficult it is to differentiate between both populations [45] and more dense information (molecular, genealogical and phenotypical) is necessary. As demonstrated by analyses of composite Swiss Fleckvieh breed [53], when pedigree records of admixed animals were deep and known to their pure ancestors then the correlation between pedigree-based and genome-based admixture was very high (0.972). However, the common characteristic of the endangered indigenous breeds under low management level is absence of such dense genealogical information. Also, the dataset of 76 Cika with relatively good quality of pedigree records contained 13 animals with unknown both parents as well as six animals with unknown sire. All these were recorded as 100% pure Cika in a herd book. Consequently, the correlation between pedigree-based and genome-based admixture of 76 Cika animals was lower (0.72). It needs to be repeatedly emphasized that studies estimating parameters and developing tools (e.g. [53] by necessity use designs with denser information and by the majority include samples of cosmopolitan breeds where lower effect of ascertainment bias could be expected then in the indigenous breeds.

Populations of livestock animals are characterised by several introgression events since domestication. In cattle, some of these events are known as secondary domestication, mostly due to the influence of wild aurochs males on domestic dam populations [54]. These ancient introgressions were combined with several long-distance migration events in the time before the industrial revolution and the subsequent foundation of modern breeds. Many local well-adapted strains have never been intensively managed and differentiated into regular breeds [3]. It is difficult (if at all necessary) to draw a clear line between the ancient and modern introgression events. Accordingly, the goal of this and the future studies aiming for restoration and conservation of the domestic breeds is not the ultimate recovery of the native genetic background but rather to stop ongoing erosion of genetic identity, to preserve diversity within the breed and, if possible, thereby to increase the proportion of native parts of chromosomes without the overall loss of diversity and increased rate of inbreeding.

Conclusions

Each population is dynamic with a different identity and should be considered on an individual basis, but the following overall conclusions can be drawn from the results of this study. Combined phenotype, pedigree, and genome-wide information can be used to detect the "purest" individuals to be used as the nucleus for recovery of the native genetic background of the admixed domestic population. The ascertainment bias introduced in the construction of SNP arrays must be taken into consideration while estimating diversity and phylogeny parameters as well as for the removal of introgressed genetic material. The successful implementation of a conservation and recovery approach will benefit from a design which includes the most complete spectrum of possible source haplotypes.

Supporting Information

S1 Fig. The maximum likelihood (ML) tree inferred from genome-wide allele frequency data by methods implemented in the *TreeMix* program. A) The ML dendrogram of the relationships between 15 sampled populations rooted by African taurine N'Dama cattle. B) ML tree of 15 cattle populations assuming one migration event. C-E) Three variants of ML tree of 15 cattle populations assuming two migration events. F-G) Two variants of ML tree of 15 cattle populations assuming three migration events.
(PDF)

S2 Fig. The *Admixture* analyses of two data sets at various levels of *K*, from 2 to 16. A dataset with all 76 Cika animals **(a)** and a reduced dataset with 26 Cika animals **(b)**. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau—Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian—Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.
(PDF)

S3 Fig. Individual D_{PS} distance matrix in the two-dimensional space. Animals with D_{PS} distance below global average were connected by thin grey line. A) Highlighting a set of 55 pure Cika animals recognised by merged information of haplotype, pedigree data and type traits classification, B) a set of 47 pure Cika animals recognised only by pedigree data were highlighted, C) a set of 58 pure Cika animals recognised only by type traits classification. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; API, Pinzgauer; SIC, Cika; SIC-F, inbreed SIC animal; SIC*FGV*DFV, SIC related to FGV and DFV; SIC*API(I), SIC related to particular API animal; SIC*API(P), SIC related to API population; SIC-F*RHF, inbreed SIC animal related to RHF; SIC*RHF, SIC related to RHF.
(PDF)

S1 Table. Correlations among type traits classifications, pedigree, genome-wide relationship (IBD) and the proportion of genes from *ADMIXTURE* analysis.
(DOCX)

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Author Contributions

Conceived and designed the experiments: MS DK IM. Performed the experiments: MS DS IM. Analyzed the data: MS AS DS JS IM. Contributed reagents/materials/analysis tools: JS DS IM. Wrote the paper: MS GG DK IM.

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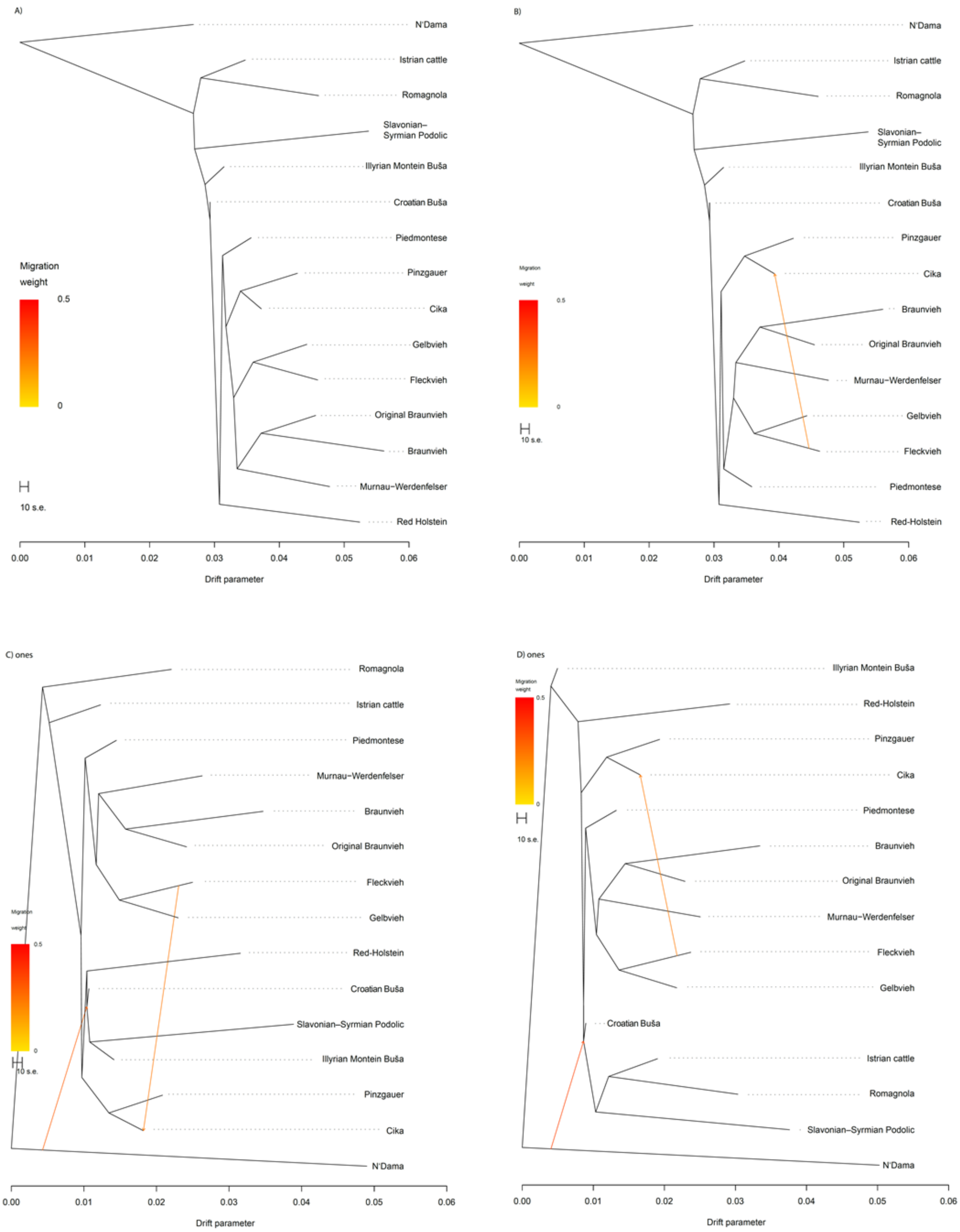
A)
N'Dama
Istrian cattle
Romagnola
Slavonian–Syrmian Podolic
Illyrian Montein Buša
Croatian Buša
Piedmontese
Pinzgauer
Cika
Gelbvieh
Fleckvieh
Original Braunvieh
Braunvieh
Murnau–Werdenfelser
Red Holstein
Migration weight
0.5
0
10 s.e.
0.00 0.01 0.02 0.03 0.04 0.05 0.06
Drift parameter
B)
N'Dama
Istrian cattle
Romagnola
Slavonian–Syrmian Podolic
Illyrian Montein Buša
Croatian Buša
Pinzgauer
Cika
Braunvieh
Original Braunvieh
Murnau–Werdenfelser
Gelbvieh
Fleckvieh
Piedmontese
Red-Holstein
10 s.e.
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Romagnola
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Murnau–Werdenfelser
Braunvieh
Original Braunvieh
Fleckvieh
Gelbvieh
Red-Holstein
Croatian Buša
Slavonian–Syrmian Podolic
Illyrian Montein Buša
Pinzgauer
Cika
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Red-Holstein
Pinzgauer
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Original Braunvieh
Murnau–Werdenfelser
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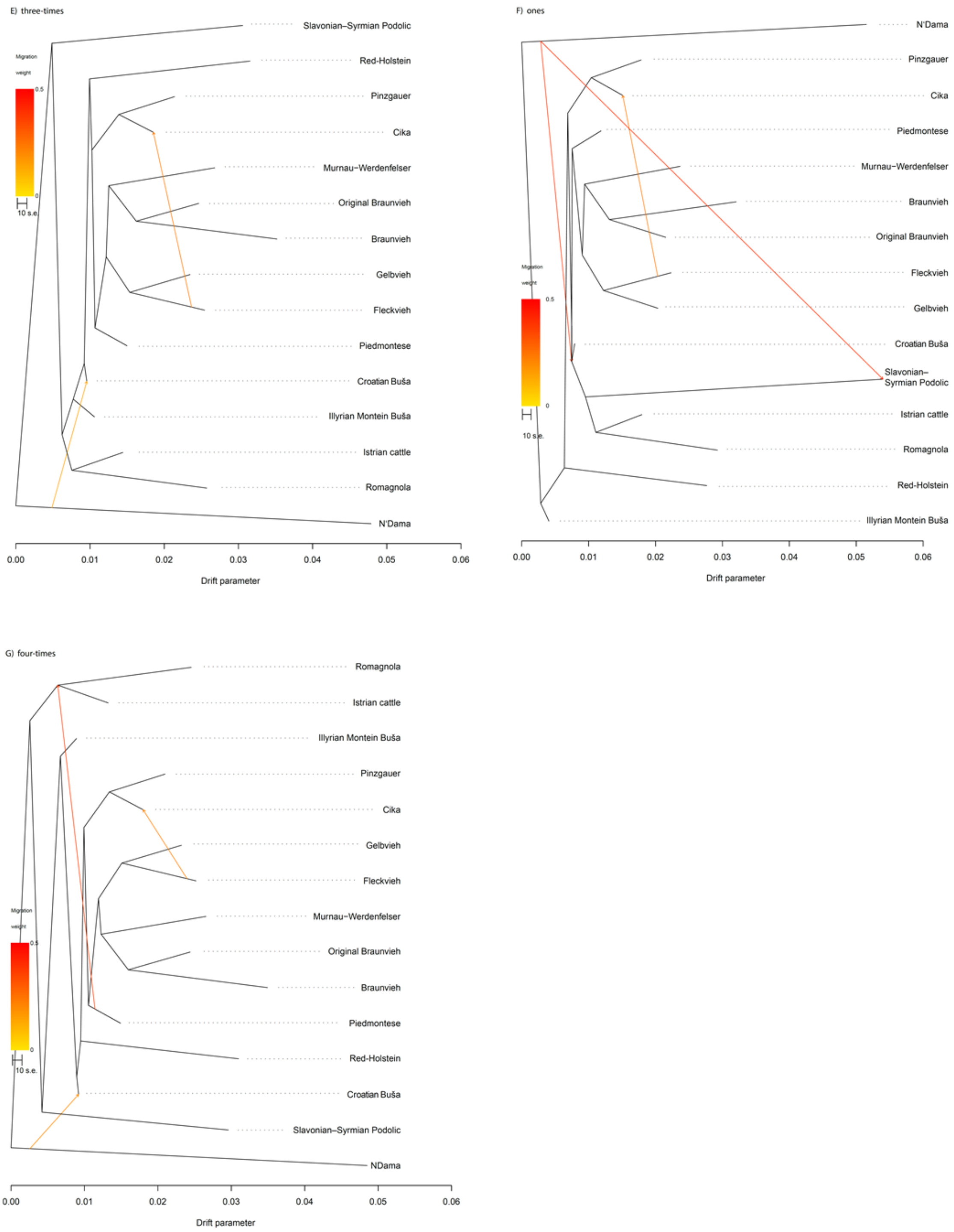
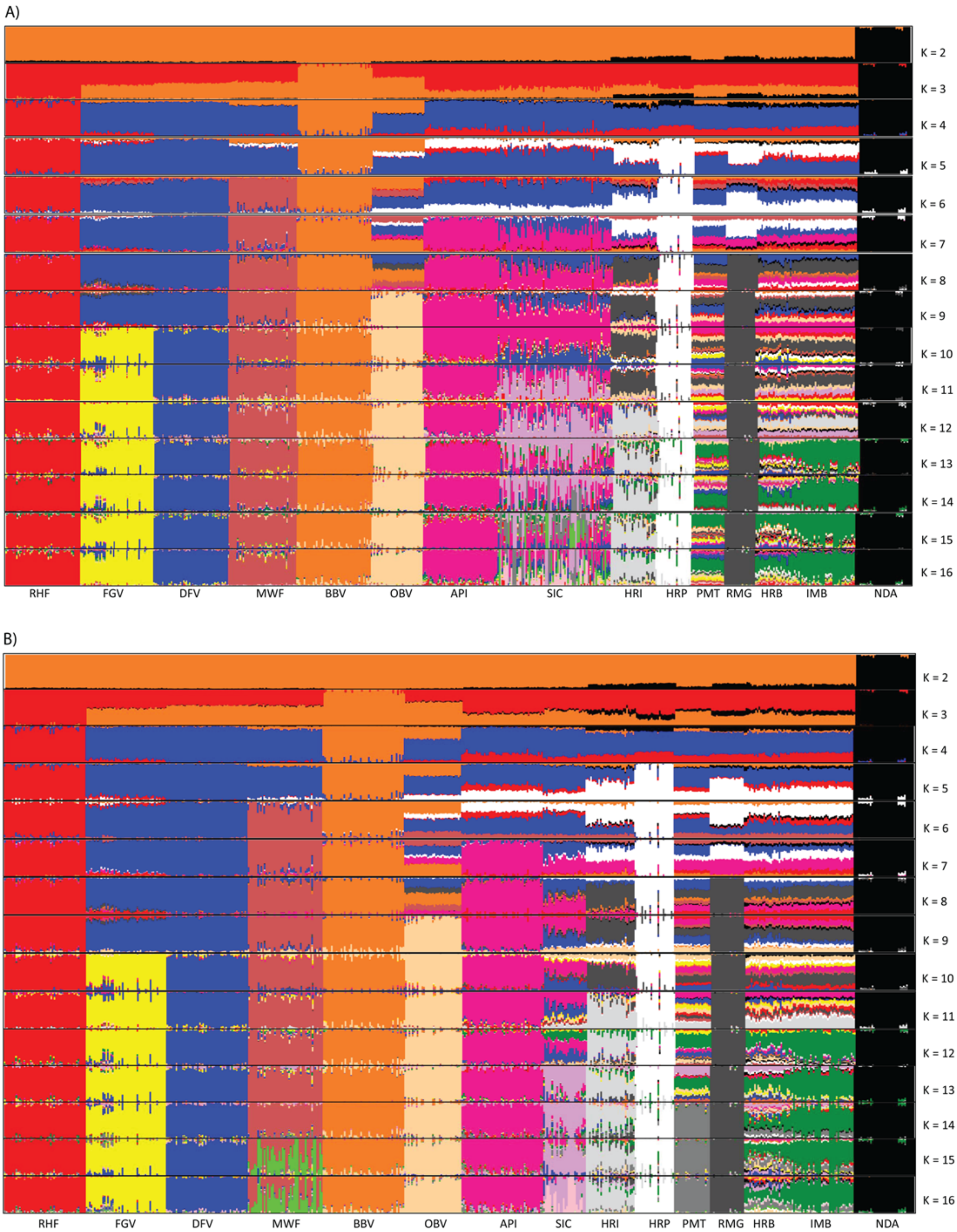
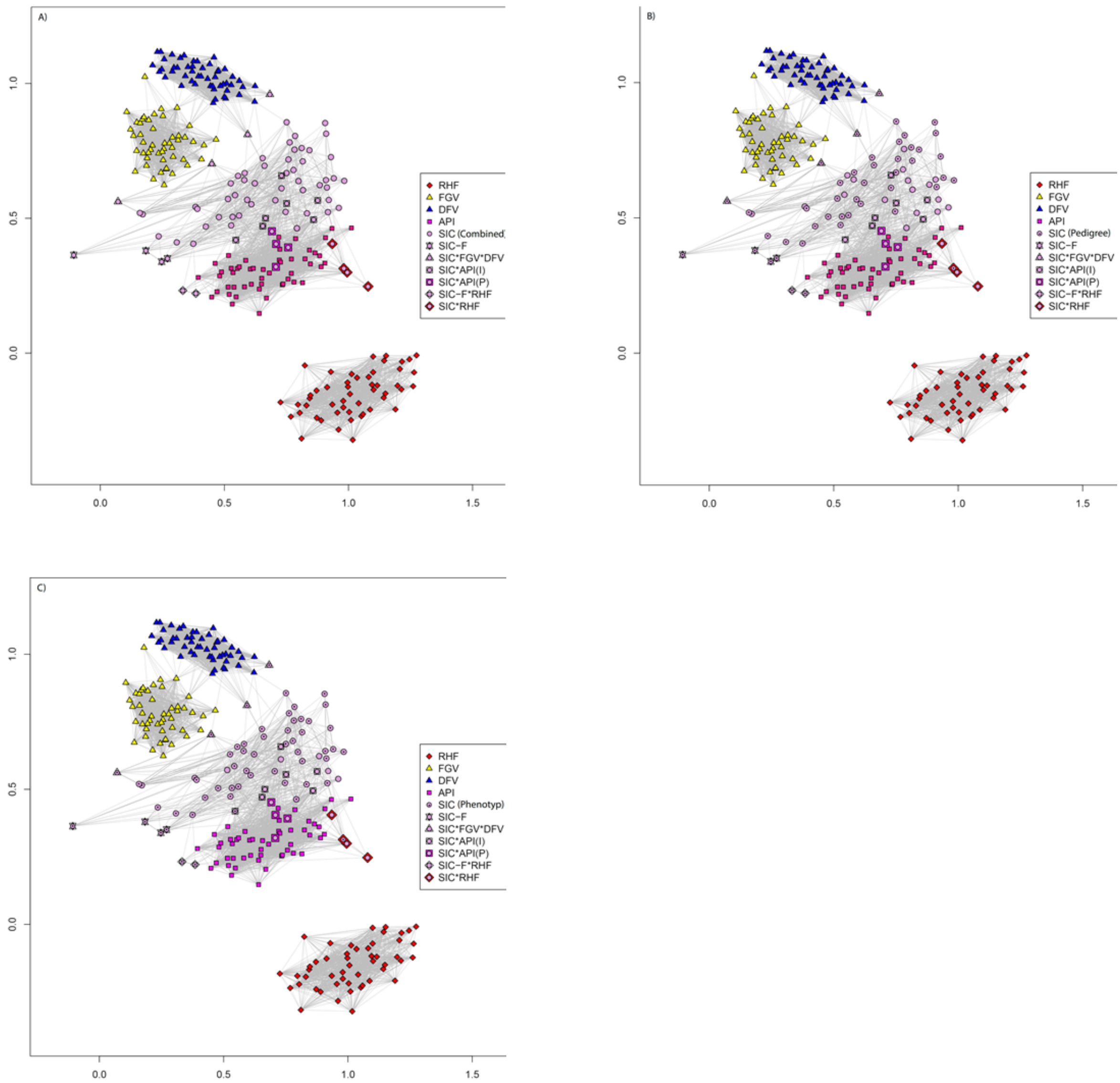


S1 Fig. The maximum likelihood (ML) tree inferred from genome-wide allele frequency data by methods implemented in the *TREEMIX* program. A) The ML dendrogram of the relationships between 15 sampled populations rooted by African taurine N'Dama cattle. B) ML tree of 15 cattle populations assuming one migration event. C-E) Three variants of ML tree of 15 cattle populations assuming two migration events. F-G) Two variants of ML tree of 15 cattle populations assuming three migration events.



S2 Fig. The *ADMIXTURE* analyses of two data sets at various levels of *K*, from 2 to 16. A dataset with all 76 Cika animals **(a)** and a reduced dataset with 26 Cika animals **(b)**. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; MWF, Murnau – Werdenfelser; BBV, Braunvieh; OBV, Original Braunvieh; API, Pinzgauer; SIC, Cika; HRI, Istrian cattle; HRP, Slavonian – Syrmian Podolic; PMT, Piedmontese; RMG, Romagnola; HRB, Croatian Buša; IMB, Illyrian Mountain Buša; NDA, N'Dama.



S3 Fig. Individual D_{PS} distance matrix in the two-dimensional space. Animals with D_{PS} distance below global average were connected by thin grey line. A) Highlighting a set of 55 pure Cika animals recognised by merged information of haplotype, pedigree data and type traits classification, B) a set of 47 pure Cika animals recognised only by pedigree data were highlighted, C) a set of 58 pure Cika animals recognised only by type traits classification. RHF, Red Holstein; FGV, Franken Gelbvieh; DFV, German Fleckvieh; API, Pinzgauer; SIC, Cika; SIC-F, inbreed SIC animal; SIC*FGV*DFV, SIC related to FGV and DFV; SIC*API(I), SIC related to particular API animal; SIC*API(P), SIC related to API population; SIC-F*RHF, inbreed SIC animal related to RHF; SIC*RHF, SIC related to RHF

S1 Table. The table with correlations among type traits classifications, pedigree, genome-wide relationship (IBD) and the proportion of genes from ADMIXTURE analysis.

	Type traits classification	IBD (SIC-API)	SIC genes (Pedigree)	API genes (Pedigree)	SIC genes (*ADMIXTURE*)	API genes (*ADMIXTURE*)
Type traits classification	1.00					
IBD (SIC-API)	0.65***	1.00				
SIC genes (Pedigree)	-0.73***	-0.67***	1.00			
API genes (Pedigree)	0.71***	0.69***	-0.98***	1.00		
SIC genes (*ADMIXTURE*)	-0.53***	-0.55***	0.60***	-0.58***	1.00	
API genes (*ADMIXTURE*)	0.65***	0.95***	-0.70***	0.72***	-0.73***	1.00

SIC, Cika; API, Pinzgauer

2.4 VPLIV DVEH RAZLIČNIH KRMNIH OBROKOV OB KONCU PITANJA NA PRIRAST, KLAVNE LASTNOSTI IN OBNAŠANJE OB KRMLJENJU PRI BIKIH CIKASTE IN LISASTE PASME V SLOVENIJI

Effects of two finishing diets on growth performance, carcass characteristics and feeding behaviour of Slovenian Cika and Simmental young bulls

Silvester Žgur, Marta Brščić, Mojca Simčič, Nežika Petrič, Marko Čepon, Giulio Cozzi

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Izvleček:

Cilj raziskave je bil ugotoviti kako tradicionalen način dopitanja s krmnim obrokom na osnovi voluminozne krme v primerjavi s krmnim obrokom z večjo energijsko vrednostjo vpliva na rast, klavne lastnosti in obnašanje ob krmljenju pri bikih cikaste in lisaste pasme (20 bikov na pasmo). Poskusna krmna obroka sta bila: extenzivni (EXT) na osnovi travne silaže in srednje intenzivni (S-INT), v katerem je bil del voluminozne krme nadomeščen s koruzno silažo in sončnično moko. Oba krmna obroka sta bila krmljena *po želji* desetim bikom cikaste (starost 547 dni) in desetim bikom lisaste pasme (starost 442 dni), ki so bili uhlevljeni v skupinskih boksih po pet živali skupaj. Zmogljivost za rast je bila podobna pri bikih obeh pasem, vendar so biki cikaste pasme dosegli komercialno stopnjo dopitanosti en mesec pred biki lisaste pasme (139 *vs.* 167 dni, p = 0,016). Biki krmljeni s S-INT obrokom so imeli večjo telesno maso ob zakolu (645,3 *vs.* 590,1 kg; p = 0,05), povprečni dnevni prirast (1,05 *vs.* 0,83 kg, p = 0,026) in zauživanje krme (11,7 *vs.* 10,6 kg suhe snovi (SS)/dan, p < 0,001) kot biki krmljeni z EXT obrokom. Ne glede na pasmo in krmni obrok so biki zaužili 77 – 80 % dnevne SS v prvih osmih urah po pokladanju krme. Biki krmljeni z EXT obrokom so dlje časa stali (406,4 *vs.* 355,8 min, p < 0,001) in uživali krmo (217,2 *vs.* 155,3 min, p <0,001) in krajši čas prežvekovali (77,5 *vs.* 92,9 min; p < 0,001) kot S-INT krmljeni biki v prvih osmih urah po pokladanju krme. Biki cikastega goveda so imeli lažji polni vamp in kapico glede na relativno telesno maso ob zakolu (8,7 *vs.* 10,7 %; p = 0,002) kot biki lisastega goveda. Pozitivni rezultati doseženi s cikastim govedom bi morali spodbuditi rejce, da bi dopitali mlade bikce za prirejo mesa, s čimer bi prispevali k ohranitvi tega živalskega genskega vira. Poleg tega bi morali povečati tudi delež energije v krmnih obrokih na osnovi voluminozne krme z dodajanjem močnih krmil.

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Effects of two finishing diets on growth performance, carcass characteristics and feeding behaviour of Slovenian Cika and Simmental young bulls

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Abstract. This study aimed at comparing the effects of a traditional finishing roughage-based diet and a higher energy diet, on growth, carcass characteristics, and feeding behaviour of Slovenian Cika and Simmental bulls (20 per breed). The experimental diets were: extensive (EXT) based on grass silage, and semi-intensive (S-INT) in which a part of the roughage was replaced with maize silage and sunflower meal. Each diet was fed *ad libitum* to 10 Cika (547 days old) and 10 Simmental (442 days old) bulls housed in group pens of five animals each. Growth performance was similar in both breeds, but Cika reached commercial finishing 1 month earlier than Simmental (139 vs 167 days; $P = 0.016$). Bulls fed S-INT had higher final weight (645.3 vs 590.1 kg; $P = 0.05$), average daily growth (1.05 vs 0.83 kg; $P = 0.026$), and feed intake (11.7 vs 10.6 kg dry matter (DM)/day; $P < 0.001$) than EXT bulls. Regardless of breed and diet, bulls ate 77–80% of the daily DM in the first 8 h after feed delivery. Bulls fed EXT showed longer standing (406.4 vs 355.8 min; $P < 0.001$) and eating (217.2 vs 155.3 min; $P < 0.001$) and shorter ruminating (77.5 vs 92.9 min; $P < 0.001$) times than S-INT bulls during the first 8 h of feed delivery. Cika bulls had lower full reticulo-rumen weights relative to slaughter weights (8.7 vs 10.7%; $P = 0.002$) than Simmental. The positive findings obtained with Cika cattle should encourage farmers to finish their young Cika male stocks for beef production, thus contributing to the maintenance of this animal genetic resource, and also to increase the energy density of the grass-based finishing diets by feeding supplements.

Additional keywords: beef production, carcass quality, Cika, feeding behaviour, Simmental.

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Introduction

Cattle breeds represent an important contribution in worldwide biodiversity, but most cattle breeds have been victims of the agricultural rush to maximise dairy and beef production. In mountain areas of Northern and Western Slovenia, Cika cattle were the predominant breed until 1960, but they have been progressively replaced by breeds such as Brown Swiss and Simmental (Čepon *et al*. 1999). Similarly, ancient cattle strains raised in the Italian Alps such as Alpine Grey, Burlina, and Rendena were replaced by high-yielding dairy breeds (Cozzi and Bizzotto 2004). The Slovenian autochthone Cika cattle has a small body frame and liveweight and firm hooves and it is therefore suitable for grazing on steep slopes and is well adapted to harsh and unfavourable alpine environmental conditions (Čepon *et al.* 1999). The reduction in Cika cattle population led to a slow but progressive abandonment of the use of pastures, resulting in a change in the alpine landscape. The conservation of the autochthonous Cika breed is therefore important, not only to avoid a loss of animal genetic resources, but also to preserve the fragile alpine environment. Several measures have been successfully undertaken to improve the size of the Cika cattle population in Slovenia. In the past, Cika cattle were mainly used for milk production, whereas now, breeders are interested in traits that are important for beef production, since most of the cows are included in cow–calf production system (Simčič *et al.* 2010). The majority of Cika cattle are still raised in their native farming environment in an extensive production system based on grass silage/hay feeding with or without a limited addition of concentrates. This is consistent with several surrounding Balkan countries, where many autochthonous cattle breeds are reared under similar extensive conditions (Kompan and Cividini 2008).

The aim of this study was to compare this traditional, roughage-based feeding with a higher energy diet based on maize silage. Such an alternative beef production system could be applied to the finishing of Cika bulls in specialised fattening units in the lowland where maize crop production is feasible. Growth, carcass characteristics, and feeding behaviour of Cika bulls fed the two diets were evaluated and compared with those obtained by providing the same diets to a more cosmopolitan, dual-purpose cattle breed, the Simmental.

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Materials and methods

Animals, housing, and feeding

The study was carried out at the Educational and Research Animal Husbandry Centre Logatec of the Department of Animal Science, Biotechnical Faculty, University of Ljubljana (Slovenia). Twenty Cika and 20 Simmental young bulls (age 192–325 days) were bought from different farms throughout Slovenia in March 2010 and transferred to the Centre where they were housed in a closed barn with multiple pens for an adaptation–growing period of 200 days. During this period, all the bulls were fed the same total mixed ration (EXT) based on grass silage with a limited amount of concentrates (Table 1).

The finishing period started on October 2010. The bulls of both breeds were divided into two subgroups of 10 animals each and matched according to their liveweight (Table 2). Each subgroup within breed was then assigned to one of the experimental diets. Ten Cika and 10 Simmental bulls were kept on the extensive, total mixed ration (EXT) based on grass silage plus a small amount of maize meal to mimic the feeding plan of the small, mountain farms. The second subgroup received a semi-intensive, total mixed ration (S-INT), in which grass silage was partially replaced by maize silage and sunflower meal. Within each feeding treatment, bulls of a given breed were housed in two pens (five bulls per pen). The animals had a space allowance of 5.1 m^2/head and a space at the manger of 1.3 m/head. Each pen had a fully slatted floor and was equipped with two drinkers to allow *ad libitum* drinking water. Diets were distributed at 09 : 00 each day. An *ad libitum* intake was assured by adjusting the amount of feed delivered to each experimental pen in order to obtain approximately a recovery of 3% feed residue (as-fed basis) 24 h after delivery.

Experimental diets

The particle size distribution of each diet was measured (Table 1). Dietary samples were collected monthly throughout the study and frozen for chemical and physical analysis. Samples were analysed for dry matter, ash, and crude protein content according to the methods of the Association of Official Analytical Chemists (AOAC 1990). Neutral detergent fibre (NDF) content of the same samples was measured as described by Van Soest *et al.* (1991) and the starch content was determined by high performance liquid chromatography method (AOAC 1990). The net energy content of diets was calculated in Unité Fouragère Viande units using reference values reported by the Institute National de la Recherché Agronomique (1988) for all feed ingredients. The EXT diet had a higher dry matter (DM) and NDF content than the S-INT diet, and there was a 16% difference in the estimated net energy content between the two finishing diets (Table 1). Particle-size distribution of the dietary samples was assessed using the Penn State Forage Particle Separator (Nasco, Fort Atkinson, WI, USA). More than 50% of the feed particles in the EXT diet were retained by the top sieve of the separator, whereas the inclusion of maize silage and concentrates as partial replacement of grass silage in the S-INT diet increased

Table 1. Feed composition, chemical analysis, and particle-size distribution of the extensive (EXT) and semi-intensive (S-INT) diets (mean ± s.d.)

Variable	EXT	S-INT
Ingredients (kg as fed)		
Grass silage	9.0	2.5
Maize silage	–	10.0
Maize	2.0	1.43
Sunflower meal	–	1.07
Mineral-vitamin pre-mix[A]	0.2	0.134
Chemical analysis		
Dry matter (DM) (%)	70.0 ± 2.8	55.4 ± 2.6
Crude protein (% DM)	12.1 ± 0.3	12.3 ± 0.5
Neutral detergent fibre (% DM)	42.4 ± 1.5	37.6 ± 1.3
Starch (% DM)	16.7 ± 1.6	27.4 ± 1.4
Unité Fouragère Viande (Mcal/kg DM) (MJ/kg DM)	1.35 (5.65)	1.60 (6.69)
Particle size distribution (% as fed)		
Particles retained by 19-mm sieve	54.2 ± 9.6	16.2 ± 9.6
Particles retained by 8-mm sieve	15.6 ± 4.5	36.8 ± 11.1
Particles passing through 8-mm sieve	30.2 ± 6.4	47.0 ± 4.5

[A]Contained per kg pre-mix: Ca 188 g, Na 70 g, P 40 g, Mg 1 g, Zn 744 mg, Mn 1116 mg, Cu 297 mg, Co 30 mg, Se 3.7 mg, vitamin A 297 600 IU, vitamin D3 55 800 IU, alpha-tocopherol 372 mg.

Table 2. Least square means showing the effects of breed and diet on growth performance of young Cika and Simmental (Sim) bulls fed extensive (EXT) and semi-intensive (S-INT) diets

B, breed; D, diet; DM, dry matter

	Breed		Diet		s.e.	*P*-value		
	Cika	Sim	EXT	S-INT		B	D	B × D
Young bulls (*n*)	20	20	20	20				
Pens (*n*)	4	4	4	4				
Initial age (days)	547	442	493	496	11	0.002	0.835	0.618
Initial weight (kg)	474.7	471.9	461.8	484.8	16.5	0.911	0.381	0.774
Final weight (kg)	595.8	639.7	590.1	645.3	14.3	0.096	0.050	0.696
Finishing duration (days)	139	167	153	153	4.9	0.016	1.000	–
Average daily gain (kg/day)	0.87	1.00	0.83	1.05	0.04	0.104	0.026	0.911
Feed intake (kg DM/day)	11.1	11.2	10.6	11.7	0.04	0.158	<0.0001	0.096
Feed conversion ratio (kg DM consumed/kg liveweight gain)	12.2	11.0	12.4	10.8	0.6	0.302	0.184	0.773

the percentage of particles either retained by the middle sieve or settling on the bottom pan (Table 1).

Growth performance and health status

All bulls were weighed at the beginning of the experiment and then once per month until slaughter. Pen DM intake (DMI) was recorded three times per week. Pen feed conversion ratio was calculated by dividing daily DMI by average daily gain (ADG).

Individual health and cleanliness were checked during three observation sessions carried out between October 2010 and February 2011 at 2-month intervals. At each session, the bulls were assessed for signs of poor body condition (compared with the average of the animals belonging to the same breed), injuries, skin alterations, lameness, hampered respiration, coughing, nasal and ocular discharge, rumen bloating, tail docking, cross-sucking, and being dirty. For this purpose, a method proposed for each variable by the Welfare Quality® Assessment protocol for cattle (Welfare Quality 2009) was used.

During the three observation sessions, a trained observer assessed the consistency of the faeces at the time of defecation of each bull by using the following scale: 0, liquid; 1, loose; 2, normal; 3, firm.

Feeding behaviour and diet selection

Three behavioural observation sessions were carried out on the same days as the health checks. Each observation session lasted 8 h from 0900 to 1700 hours, starting right after diet delivery. Direct observations were performed by four trained assessors using the scan-sampling technique (Martin and Bateson 1993) with a 5-min interval between scans. Two assessors observed four pens each for 2 h consecutively in a rotation, so that during the 8-h period, each assessor observed each diet and breed. The numbers of animals per pen in a standing or lying position and eating or ruminating were recorded. Visits at the drinker were recorded using the behaviour sampling technique (Martin and Bateson 1993).

Ingestive behaviour and diet selection were measured at the observation sessions by weighing the diet left in the manger at 8 and 24 h after distribution to calculate the percentage consumed after 8 h (T0–T8) and 24 h (T9–T24). Dietary samples were collected from the mangers at separate time intervals (T0, T8, and T24) to evaluate the diet selection activity as proposed by Cozzi and Gottardo (2005). Samples were chemically analysed for NDF and starch content, and their particle-size distribution was assessed using the Penn State Forage Particle Separator. Selection indexes for NDF, for starch, and for the three fractions of particles retained by the separator were calculated for each pen by dividing the value measured in the diet residue at a given time interval by the value at the previous interval. Index values <1 indicated preferential consumption, >1 indicated selective refusal, and 1 indicated no selection (Cozzi and Gottardo 2005).

Carcass characteristics

Young bulls were slaughtered when they achieved an appropriate commercial finishing according to the Slovenian market requirements as assessed by a beef cattle expert, who considered finish to mean a slight fat cover in specific body areas such as ribs, brisket, loin, rump, and tail-head. Four slaughter sessions were carried out in the same European Union-licenced abattoir during a 7-week period from the end of February to early April 2011. Each slaughter batch comprised 10 bulls; transports one and two contained 10 Cika bulls each, five animals per diet; and transports three and four contained 10 Simmental bulls each, five animals per diet. Animals were transported to the abattoir (50 km) in the same truck and slaughtered immediately after arrival. Measures were taken to ensure that handling was the same for all animals. During the slaughtering process, head (without skin and horns), skin (without head skin), full and empty reticulo-rumen and omasum + abomasum, and pelvic and kidney fat were weighted. After slaughter, hot carcasses were weighed and dressing percentage was calculated as hot carcass weight divided by slaughter liveweight. Carcasses were graded for conformation (EUROP grid system) and fatness according to the European grading scheme (Office National Interprofessionnel des Viandes de l'Elevage et de l'Aviculture 1984).

Statistical analyses

Each separate bull was the experimental unit for data regarding growth and carcass characteristics, health status, chewing acts, cleanliness, and faecal score. Each separate pen was the experimental unit for data regarding feed intake, feed conversion ratio, behaviour, and feed selection.

Growth and slaughter data were analysed with the statistical package SAS/STAT (SAS 2001) using a MIXED procedure, considering breed, diet, and their interaction as fixed effects and pen within breed × diet as a random effect. Pen feed intake was analysed by a MIXED procedure considering breed, diet, breed × diet, and week as fixed effects and pen within breed × diet as random effect with the repeated statement for week. Feed conversion ratio was analysed by the GLM procedure considering the effects of breed, diet, and breed × diet.

Behavioural data were gathered by the scan sampling technique and transformed from absolute frequencies of events per scan into minutes, assuming that the behaviour lasted the entire time interval between two scans (Maekawa *et al.* 2002). Normally distributed behavioural data (W >0.90, Shapiro–Wilk test) and selection indexes were processed with PROC GLM using a linear model that considered the main effects of diet, breed, and observation session day and the breed × diet interaction using the Bonferroni adjustment.

Binary data of health status variables and cleanliness that showed a prevalence >0 were submitted to statistical analysis using PROC LOGISTIC (SAS 2001) to obtain odds ratio (OR) and 95% confidence intervals (CI) for each event according to the effect of diet and breed. Data with non-parametric distribution regarding faecal scores were submitted to analysis with PROC NPAR1WAY (SAS 2001) considering the same main effects. Differences were considered significant at P = 0.05 for all variables.

Results and discussion

Growth performance and health status

There was no difference between breeds in initial weight, but Cika bulls were significantly older than Simmental (Table 2). Final weight, ADG, feed intake, and feed conversion ratio were similar in both breeds. However, to achieve an appropriate commercial finishing, Simmental bulls required an extra month compared with Cika, and their growth performance was far below that obtained by Cozzi *et al.* (2009) with a more intensive feeding plan (1.76 Mcal (7.36 MJ)/kg DM). These findings suggest that, at least for the Simmental breed, both experimental diets were insufficient to produce maximum growth potential and a more efficient finishing, particularly in terms of time.

Growth performance of Cika bulls was satisfactory when compared with the recent results obtained by Simčič *et al.* (2011), who report a daily gain of 443 g/day from birth to slaughter for roughage-fed Cika bulls <2 years of age.

Compared with the EXT, the S-INT diet increased the ADG of bulls by 26%, resulting in a higher ($P < 0.05$) final weight (Table 2). The high NDF content and the fill effect of the EXT diet due to the prevalence of coarsely chopped particles (Table 1) resulted in a lower DMI than the S-INT diet. There was no diet effect on the feed conversion ratio (Table 2).

All bulls included in the trial maintained good health, except for one Simmental bull fed the S-INT diet that showed visible signs of respiratory problems and poorer body condition than the other breed-mates due to a broken rib at the onset of the study. However, this injury did not compromise the health status of the bull so severely as to require its early culling from the trial. The problem was gradually overcome with the healing of the bone. No signs of injuries, lameness, hampered respiration, coughing, nasal and ocular discharge, bloated rumen, and tail docking were detected at any of the three observation sessions. Cross-sucking signs were observed in four bulls (two Simmental EXT and two Simmental S-INT) at the first, none at the second, and two bulls (one Simmental EXT and one Cika S-INT) at the third observation session, with no significant differences due to diet, breed, or observation day. The prevalence of skin hyperkeratinisation on the dorsal part of the neck increased throughout the study involving 2.5% (one Cika), 37.5% (six Cika and nine Simmental), and 70% of the bulls (15 Cika and 13 Simmental) at the first, second, and third observation sessions ($P < 0.001$), respectively. However, the occurrence of this skin alteration was likely due to the design of the feeding barrier rather than to breed or diet effects. In contrast, the cleanliness of the bulls varied between breeds ($P < 0.001$) and diets ($P = 0.003$). The incidence of dirty bulls was lower for Cika than for Simmental bulls (OR 0.02, 95% CI 0.006–0.096), and was higher for EXT animals than those fed the S-INT diet (OR 5.12, 95% CI 1.74–15.08). No observation session effect was obtained for cleanliness ($P = 0.495$). Consistent with the outcomes for cleanliness, Cika cattle had faeces of a normal consistency, whereas Simmental bulls were observed more often to have more liquid faeces (Fig. 1*a*). Faeces of S-INT bulls had a normal consistency compared with the looser consistency for EXT bulls (Fig. 1*b*).

Feeding behaviour and diet selection

Regardless of breed ($P = 0.582$) and diet ($P = 0.483$), bulls ate 77–80% of their total daily DMI during the first 8 h after feed delivery (Table 3) and the remaining percentage during the following time interval (T9–T24), which is in line with previous studies on the eating behaviour of beef and dual-purpose cattle (Cozzi and Gottard 2005; Cozzi *et al.* 2009). Cattle spent ~6 h standing, but standing and eating times were prolonged for bulls fed the EXT diet. In addition, the time spent by bulls eating a unit of DM was longer for the EXT diet than the S-INT diet. This behaviour could be the outcome of both the higher content and the type of NDF included in the EXT diet. Extended eating time is required for the intake of coarsely

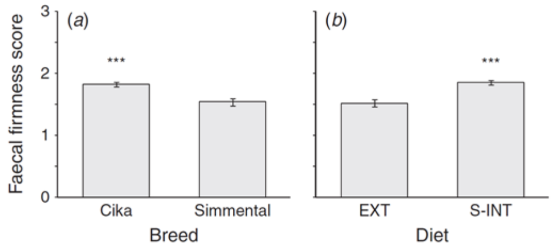

Fig. 1. Means ± standard errors showing the effect of (*a*) breed ($P = 0.001$) and (*b*) diet ($P < 0.0001$) on the faecal score of young bulls assessed during the three observation sessions at 2-month intervals. Score: 0, liquid diarrhoeic; 1, loose; 2, normal; 3, firm.

Table 3. Least square means showing the effects of breed, diet, and observation session on feed intake and behaviours in the first 8 h after diet delivery in young Cika and Simmental (Sim) bulls fed extensive (EXT) and semi-intensive (S-INT) diets

B, breed; D, diet; OBS, observation session (three observation sessions at 2-month intervals); DM, dry matter; DMI, DM intake; NDF, neutral detergent fibre

Variable in the first 8 h	Breed		Diet		s.e.	*P*-value			
	Cika	Sim	EXT	S-INT		B	D	B × D	OBS
Feed intake:									
(kg DM)	8.0	8.7	7.9	8.8	0.4	0.207	0.108	0.484	0.031
(% of daily DMI)	77.6	79.4	77.4	79.7	2.2	0.582	0.483	0.513	0.001
Time standing (min)	372.9	389.3	406.4	355.8	5.9	0.066	<0.0001	0.064	<0.0001
Time eating:									
(min)	180.4	192.0	217.2	155.3	4.5	0.088	<0.0001	0.016	<0.0001
(min/kg DM)	23.2	22.9	28.4	17.7	1.2	0.861	<0.0001	0.149	0.072
Time ruminating:									
(min)	87.3	83.2	77.5	92.9	2.6	0.275	0.001	0.485	<0.0001
(min/kg DM)	11.7	10.0	10.6	11.1	0.9	0.192	0.695	0.798	0.0002
(min/kg NDF)	25.4	22.1	22.1	25.4	1.9	0.236	0.234	0.796	0.0002

chopped, fibrous feeds, which require a prolonged chewing activity during eating. Mazzenga *et al*. (2009) showed that the eating rate of beef cattle was slowed by feeding a total mixed ration in which there was an inclusion of long particles of roughage (straw) compared with a diet in which this roughage was replaced by the shorter particles of maize silage. Similarly, dairy cows spent more time eating a total mixed ration with a 60 : 40 fibre : concentrate ratio compared with a diet in which the ratio was lowered to 43 : 57 (Maekawa *et al.* 2002). Bulls fed S-INT spent more time ruminating than those fed EXT but there was no difference between diets when this behaviour was expressed as min/kg DM or min/kg NDF (Table 3).

The number of visits at the drinkers during the 8-h observation period was also not affected by the breed ($P = 0.812$). However, EXT bulls visited the drinker in higher frequency than S-INT bulls (34.7 ± 1.71 vs 24.6 ± 1.71; $P < 0.001$). Water intake in beef cattle is positively correlated with DM content of the diet (National Research Council 2000), and this might explain the drinking behaviour of EXT bulls. Increased interest in drinking water could also contribute to their looser faecal consistency (Fig. 1*b*), with a negative impact on their cleanliness.

Selection indices showed a preferential consumption of the smallest particles for both diets in the T0–T8 time interval (Table 4). Selective behaviour towards less structured particles in the finishing diet was also observed in intensively fattened young bulls of Alpine native breeds (Alpine Grey, Rendena, and Burlina) with no difference among breeds (Cozzi *et al.* 2009). However, in the present study, this behaviour was more marked in Simmental bulls, supporting the need of this breed for a diet richer in concentrates to fulfil its greater growth potential. In the T0–T8 time interval, selective indices for long particles (19-mm sieve) and mid-size particles (8-mm sieve) were lower for EXT bulls, and this could be a further explanation for their prolonged eating time. The selection indices calculated for chemical constituents in the T0–T8 time interval confirmed a general preference across treatments for the consumption of small, starchy feed particles. In the second interval after feed delivery (T9–T24), only diet had significant effects on feed particle selection (Table 4). Bulls fed the S-INT diet kept selecting for small starch particles whereas EXT bulls had a preferential consumption for the long ones.

Carcass characteristics

At the abattoir, there was no difference between breeds for carcass weight, dressing percentage, and EUROP conformation and fatness scores (Table 5). Carcass weight, dressing percentage, and conformation score of carcasses from Simmental bulls were similar to those reported by Albertí *et al.* (2008), but due to the low energy content of our finishing diets, the animals were 5 months older at slaughter and carcasses had a lower fatness score.

Simčič *et al*. (2011) reported a carcass weight of 267 kg for roughage-fed Cika bulls <2 years of age. Results of the present study were extremely encouraging since carcasses of Cika bulls of similar age weighed 333 kg. Moreover, Cika had a lower proportional weight of the full rumen and reticulum at slaughter weight compared with Simmental. This outcome is consistent with the findings by Cozzi *et al*. (2009) for the autochthonous, dual-purpose breeds raised in the Italian Alps. Bulls finished with the S-INT diet had heavier carcass than the bulls fed the EXT diet; however, no differences were observed for EUROP and fatness scores (Table 5). Several studies on beef cattle (Keane and Allen 1998; Berthiaume *et al.* 2006; Marino *et al.* 2006) reported a positive effect on carcass weight from an increase in the energy density of low-energy diets. Breed and diet effects were not significant for the other fifth-quarter traits.

Final liveweights and carcass traits of Cika bulls obtained in this trial should encourage farmers to finish their young Cika

Table 4. Least square means showing the effects of breed, diet, and observation session on selection for dietary particles and chemical constituents by young Cika and Simmental (Sim) bulls fed the extensive (EXT) and semi-intensive (S-INT) diets during two subsequent daytime intervals after diet delivery

B, breed; D, diet; OBS, observation session; T0–T8, 0–8 hours after diet delivery; T9–T24, 9–24 h after diet delivery; NDF, neutral detergent fibres. A selection index is the proportion remaining after 8 and 24 h relative to the proportion offered: <1, preferential consumption; >1, selective refusal; 1, no selection

Selection index	Breed		Diet		s.e.	*P*-value			
	Cika	Sim	EXT	S-INT		B	D	B × D	OBS
				T0–T8					
For particles:									
Retained by 19-mm sieve	1.38	1.39	1.22	1.54	0.07	0.945	0.004	0.667	0.200
Retained by 8-mm sieve	1.04	1.17	0.93	1.28	0.11	0.404	0.035	0.871	0.463
Passing 8-mm sieve	0.68	0.61	0.67	0.61	0.02	0.049	0.127	0.958	<0.0001
For chemical constituents:									
Neutral detergent fibre	1.06	1.08	1.05	1.08	0.01	0.901	0.137	0.518	0.039
Starch	0.88	0.86	0.87	0.86	0.04	0.727	0.777	0.638	0.034
				T9–T24					
For particles:									
Retained by 19-mm sieve	0.90	0.86	0.75	1.02	0.06	0.688	0.008	0.694	0.0004
Retained by 8-mm sieve	0.77	1.67	1.12	1.33	0.51	0.230	0.775	0.233	0.060
Passing 8-mm sieve	0.99	0.93	1.13	0.79	0.06	0.428	0.001	0.838	0.001
For chemical constituents:									
Neutral detergent fibre	0.99	0.99	0.97	1.00	0.01	0.893	0.078	0.359	0.005
Starch	1.07	1.04	1.10	0.91	0.04	0.537	0.090	0.887	0.002

Table 5. Least-squares means showing the effects of breed and diet on slaughter performance and fifth-quarter traits of young Cika and Simmental (SIM) bulls fed the extensive (EXT) and semi-intensive (S-INT) diets during the finishing period
B, breed; D, diet

	Breed		Diet		s.e.	*P*-value		
	Cika	Sim	EXT	S-INT		B	D	B × D
Young bulls (*n*)	20	20	20	20				
Carcass weight (kg)	332.7	348.7	320.6	360.8	10.2	0.327	0.049	0.544
Dressing (%)	55.8	54.4	54.3	55.9	0.5	0.136	0.101	0.341
EUROP conformation (score)[A]	9.1	8.8	8.7	9.2	0.4	0.559	0.459	0.673
Fatness (score)[B]	5.4	5.1	5.1	5.4	0.3	0.406	0.406	0.901
		Fifth-quarter traits (% slaughter weight)						
Full rumen + reticulum	8.7	10.7	10.4	9.0	0.2	0.002	0.007	0.191
Empty rumen + reticulum	1.7	1.7	1.8	1.7	0.03	0.350	0.225	0.360
Full omasum + abomasum	2.5	2.4	2.5	2.4	0.1	0.737	0.366	0.765
Empty omasum + abomasum	1.3	1.4	1.4	1.4	0.04	0.328	0.599	0.979
Pelvic and kidney fat	1.1	0.8	0.8	1.0	0.1	0.118	0.155	0.904
Skin	7.2	7.4	7.2	7.4	0.3	0.547	0.775	0.338
Head	2.6	2.5	2.6	2.5	0.1	0.561	0.250	0.842

[A]1, Poor; 15, excellent+. [B]1, Minimum; 15, maximum.

bulls for beef production, thus contributing to the maintenance of this animal genetic resource. In this scenario, a significant improvement in cattle growth performance could be achieved by increasing the energy density of the traditional, extensive grass silage/hay based production system by feeding supplements.

Conclusions

The outcome of the study clearly indicates that the finishing of young bulls for beef production can be a practical solution to preserve the autochthonous Cika breed. For this purpose, it is advisable to increase the energy density of the traditional roughage-based diets currently used in Slovenia and in the Balkan countries. The results of the study prove that a partial substitution of grass silage with maize silage and sunflower meal in the S-INT diet improved growth of the animals assessed, but for Simmental bulls, it was insufficient to enable them to express their full growth potential.

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2.5 ZNAČILNOSTI KLAVNIH LASTNOSTI IN LASTNOSTI MESA PRI MLADIH BIKIH AVTOHTONEGA CIKASTEGA GOVEDA

Characterisation of indigenous Cika cattle in relation to carcass and meat quality of young bulls

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Neobjavljeno delo

Izvleček:

Primerjali smo klavno kakovost in kakovost mesa 20 mladih bikov avtohtone cikaste pasme in 20 mladih bikov lisaste pasme vzrejenih na osnovi dveh različnih krmnih obrokov pri vsaki pasmi. Deset bikov cikaste in deset bikov lisaste pasme je bilo krmljenih z ekstenzivnim popolnim krmnim obrokom na osnovi travne silaže z dodano manjšo količino koruzne moke. Ostalih 10 bikov cikaste pasme in 10 bikov lisaste pasme je bilo krmljenih s srednje intenzivnim popolnim krmnim obrokom, v katerem je bila travna silaža delno zamenjana s koruzno silažo in sončnično moko. Klavne lastnosti in lastnosti mesa smo analizirali s statističnim paketom SAS/STAT z uporabo procedure GLM. V model smo vključili sistematska vpliva pasma in krma. Za analizo sestave maščobnih kislin smo v model vključili sistematske vplive pasma, krma in interakcija pasma × krma. Cikasti biki so imeli neznačilno manjšo maso klavnega trupa (332,64 ± 6,63 kg) in značilno večjo klavnost (55,79 ± 0,35 %), v primerjavi z biki lisaste pasme (348,72 ± 6,63 kg; 54,42 ± 0,35 %). Cikasti in lisasti biki so imeli podobno svetlo (L*) meso (35,63 ± 0,36; 35,86 ± 0,36), medtem ko so imeli cikasti biki značilno bolj rdeče (a* = 24,98 ± 0,58) in bolj rumeno (b* = 11,56 ± 0,35) meso od lisastih bikov (a* = 21,55 ± 0,58, b* = 9,83 ± 0,35). Z disekcijo desne klavne polovice smo dobili 73,66 ± 0,37 % mesa, 9,51 ± 0,36 % loja, 1,48 ± 0,05 % kit in 15,35 ± 0,21 % kosti v polovici cikastih bikov, medtem so bile polovice lisastih bikov sestavljene iz 73,37 ± 0,37 % mesa, 8,20 ± 0,36 % loja, 1,81 ± 0,05 % kit in 16,63 ± 0,21 % kosti. Warner-Bratzlerjeva strižna sila je bila nekoliko večja pri vzorcih mesa lisastih bikov (49,32 ± 3,92 N) v primerjavi s cikastimi biki (43,16 ± 3,91 N), a razlika ni bila statistično značilna. Vsebnost skupne intramuskularne maščobe je bila značilno večja v mesu cikastih bikov (24,06 ± 1,95 g/kg) v primerjavi z lisastimi biki (13,02 ± 1,95 g/kg), kar bi bilo mogoče pojasniti s starostjo ob zakolu pri bikih lisaste pasme glede na to, da vpliv krme ni bil značilen. Meso cikastih bikov je vsebovalo značilno več SFA (nasičenih maščobnih kislin) (48,61 ± 0,36 %) in manj PUFA (večkrat nenasičenih maščobnih kislin) (12,65 ± 1,10 %) v primerjavi z lisastimi biki (45,28 ± 0,36 %; 18,28 ± 1,10 %). Krma ni značilno vplivala na delež SFA, MUFA (enkrat nenasičenih maščobnih kislin) in PUFA v mesu obeh pasem. Rezultati te raziskave so

pokazali, da lahko s cikastimi biki priredimo meso dobre kakovosti. Fizikalne in kemijske lastnosti so primerljive s kakovostjo mesa bikov lisaste in nekaterih drugih pasem govedi v Evropi, katerih rejci so že našli »lokalne tržne niše« za proizvode teh pasem.

ABSTRACT

Carcass and meat quality characteristics of 20 indigenous Cika and 20 Simmental young bulls from two different diets within each breed were compared. Ten Cika and ten Simmental bulls received the extensive total mixed ration based on the grass silage plus a smaller amount of maize meal. The other 10 Cika and 10 Simmental received a semi-intensive total mixed ration, in which grass silage was partially replaced by maize silage and sunflower meal. Carcass and meat traits were analysed with the statistical package SAS/STAT using a GLM procedure, considering breed and diet as fixed effects. Fatty acids profile was analysed considering breed, diet and breed × diet interaction as fixed effects. Cika bulls had non-significantly lower carcass weight (332.64 ± 6.63 kg) and significantly higher dressing percentage (55.79 ± 0.35%) compared to the bulls of Simmental breed (348.72 ± 6.63 kg; 54.42 ± 0.35%). Cika and Simmental young bulls had similarly light (L*) meat (35.63 ± 0.36; 35.86 ± 0.36), while Cika bulls had significantly more red (a* = 24.98 ± 0.58) and more yellow (b* = 11.56 ± 0.35) meat than Simmental (a* = 21.55 ± 0.58; b* = 9.83 ± 0.35), respectively. The dissection of right carcass sides resulted in 73.66 ± 0.37% of lean meat, 9.51 ± 0.36% of total fat, 1.48 ± 0.05% of tendons and 15.35 ± 0.21% of bones in Cika carcasses, while 73.37 ± 0.37% of lean meat, 8.20 ± 0.36% of total fat, 1.81 ± 0.05% of tendons and 16.63 ± 0.21% of bones in Simmental carcasses. Warner-Bratzler shear force were slightly higher in Simmental (49.32 ± 3.92 N) compared to Cika samples (43.16 ± 3.91 N), but the difference was not significant. Total intramuscular fat content was significantly higher in Cika beef (24.06 ± 1.95 g/kg) compared to Simmental (13.02 ± 1.95 g/kg) what could be explained with lower slaughter age of Simmental young bulls regarding that the effect of the diet was not significant. Cika beef contained significantly more SFA (48.61 ± 0.36%) and less PUFA (12.65 ± 1.10%) compared to Simmental (45.28 ± 0.36%; 18.28 ± 1.10%), respectively. However, the diet did not significantly affect the percentage of SFA, MUFA, PUFA in beef of both breeds. The findings from this study show that Cika young bulls can provide meat of good quality. Physical and chemical characteristics seem to be comparable to meat quality of Simmental and some other breeds of cattle in Europe which have already found a “local niche” for their products.

Keywords: Cika cattle, carcass traits, meat quality, sensory quality, fat, fatty acids

INTRODUCTION

Cika cattle is an indigenous breed in Slovenia more precisely described in other papers (Simčič et al., 2013). In the past, it was traditionally kept for milk production especially in the regions where Alpine dairy-farming prevailed. Nowadays, Cika is mostly reared in the cow-calf system for beef production and to a smaller extend for milk production and processing. Breed is excellently adapted to harsh environmental conditions like grazing on slope mountain pastures and is mainly spread in mountain and marginal areas. Breed is considered as dual-purpose (dairy, meat) cattle with medium sized body frame. In 2014, the population of Cika cattle was numbering 3351 animals in total (Sector for Identification and Registration at the Ministry for Agriculture, Forestry and Food).

Husbandry of indigenous breeds in protected areas provides an opportunity for sustainable use of natural ecosystems and supports socio-economic development of marginal areas (Marino et al., 2006). Several studies have been reported to show carcass and meat quality of young bulls belonging to some European beef and dual-purpose breeds, as well as autochthonous breeds (Albertí et al., 2008). Some papers consider traditional production systems for fattening young bulls of autochthonous breeds (Piedrafita et al., 2003; Serra et al., 2004; Marino et al., 2006), while other authors try to promote the intense fattening of autochthonous young bulls to show their potential for beef production (Cozzi et al., 2009; Özlütürk et al., 2004). It is well known that fattening technology also affects consumer's preferences when choosing beef. Those preferences include both, the ecological, as well as ethological aspects.

According to our best knowledge, little information about fatty acid composition in beef of indigenous cattle breeds is available in the literature. Nowadays, it is widely known that fatty acid composition in meat has an implication on the human health. In addition, fatty acid composition affects the sensory traits of meat (Oliver et al., 2006).

Simčič et al. (2008) analysed carcass traits of slaughtered Cika cattle from commercial slaughtering. Unfortunately, there were no known data about rearing technology and its effect on the carcass and meat quality of Cika cattle. Beef from a specific production system represents the combined effects of breed, genotype, sex, age, nutrition and management, and these effects can interact at many points (Raes et al., 2003). To provide similar environmental conditions fattening trial with Cika young bulls was performed. Cika young bulls were fed two different diets (semi-intensive *vs*. extensive) and were compared to the well-known Simmental young bulls. So, the aim of this study was to investigate some carcass and meat quality traits of indigenous Cika cattle.

MATERIAL AND METHODS

Animals, diets and slaughter

This study included 20 young bulls of indigenous Cika cattle and for comparison 20 young bulls of Simmental cattle. Weaned bulls were selected from different herds all over Slovenia and housed at the Educational and research animal husbandry centre Logatec of the Department of Animal Science, Biotechnical Faculty, University of Ljubljana as was precisely described elsewhere (Žgur et al., 2014). Two different diets were used. Ten Cika and ten Simmental bulls received the extensive total mixed ration (EXT) based on the grass silage plus a small amount of maize meal to mimic the feeding plan of the small mountain farms. The other 10 Cika and 10 Simmental bulls received a semi-intensive total mixed ration (S-INT), in which grass silage was partially replaced by maize silage and sunflower meal. Diet samples were analysed for dry matter, ash, crude protein, neutral detergent fibre and starch content. Bulls were weighted once per month. Young bulls were slaughtered when they achieved an appropriate commercial finishing according to the Slovenian market. They were visually assessed by a beef cattle expert who determined slight fat cover in specific body areas such as ribs, brisket, loin, rump and tailhead (Žgur et al., 2014). S-INT fed Cika young bulls were slaughtered in average at 673.50 ± 32.5 days compared to the EXT fed bulls (678.50 ± 23.0 days), while they achieved larger slaughter weight (619.1 ± 41.4 kg; 572.4 ± 36.9 kg), respectively. Simmental young bulls were younger at slaughter (S-INT = 606.8 ± 38.7 days, EXT = 595.3 ± 31.8 days) compared to Cika young bulls and achieved 671.5 ± 53.5 kg and 607.8 ± 45.4 kg slaughter weight, respectively.

Table 1: Diets composition and chemical analysis of the extensive (EXT) and semi-intensive (S-INT) diets (Žgur et al., 2014)

Variable	Diet (mean ± SD)	
	EXT	S-INT
Ingredients (kg as fed)		
- Grass silage	9.0	2.5
- Maize silage	-	10.0
- Maize	2.0	1.43
- Sunflower meal	-	1.07
- Mineral-vitamin pre-mix†	0.2	0.134
Chemical analysis		
- Dry matter (%)	70.0 ± 2.8	55.4 ± 2.6
- Crude protein (% DM)	12.1 ± 0.3	12.3 ± 0.5
- NDF (% DM)	42.4 ± 1.5	37.6 ± 1.3
- Starch (% DM)	16.7 ± 1.6	27.4 ± 1.4
- Unité Fouragère Viande (Mcal/kg DM)	1.35	1.60

†Contained per kg of pre-mix: Ca 188 g; Na 70 g; P 40 g; Mg 1 g; Zn 744 mg; Mn 1116 mg; Cu 297 mg; Co 30 mg; Se 3.7 mg; Vitamin A 297600 UI; Vitamin D3 55800 UI; Alpha-tocopherol 372 mg.

Carcass traits

After slaughter, carcasses were split and hot carcass weight, carcass length as well as chest depth were recorded. Carcass length was measured as the distance from the anterior edge of the symphysis pubis to the middle of the anterior edge of the visible part of the first rib. Chest depth is the distance from the ventral edge of the spinal canal to the ventral edge of the broken sternum of the fifth rib. Dressing percentage was calculated as a quotient between carcass weight and slaughter weight. Conformation index was computed as a quotient between carcass weight and the product of carcass length and chest depth. Carcass sides were chilled at 4°C for 24 hours.

The pH value, electrical conductivity and meat colour were measured 24h after the slaughter and just before dissection procedure on the cross section of *Longissimus dorsi* muscle behind the 6th rib. pH value was measured using a pH-meter equipped with a penetrating electrode. The electrical conductivity was assessed with a LF/PTSTAR (Matthäus) conductometer. Meat colour was measured using chromo meter (Minolta CR 300). Before measurement, cut surface was allowed to bloom for 30 min at 4°C. The following CIE colour coordinates (CIE, 1986) were measured: lightness ($L*$), redness ($a*$) and yellowness ($b*$) from three locations on the cut surface of the *Longissimus dorsi.* Marbling was assessed and subjectively scored on the cut surface of *Longissimus dorsi* in the scale from 1 to 9 against the AUS-MEAT marbling reference standards (Australian Beef…, 2014).

Carcass dissection and sampling

After 24h of chilling dissection of the right carcass side according to DLG method (Scheper and Scholz, 1985) was carried in the Experimental slaughter and dissection house at the Department of Animal Science. The main commercial cuts (chuck, shoulder, front shank, rib roast, back, loin, tender loin, brisket, rib, flank, leg, hind shank) were separated into the main carcass tissues (lean meat, subcutaneous fat, intermuscular fat, tendons and bones) and weighted using calibrated scale. Total weight of the main cuts and the total weight of separated tissues within each main cut were used to calculate the proportions of five various tissues in the carcass. Likewise, lean meat to bones as well as lean meat to the total fat ratio were calculated.

Longissimus dorsi area in the cross section between 6th and 7th rib was traced as the perimeter of the area on the paus paper. Lately, the area was calculated with a compensating polar planimeter, which is an instrument that measures the area of irregularly shaped objects.

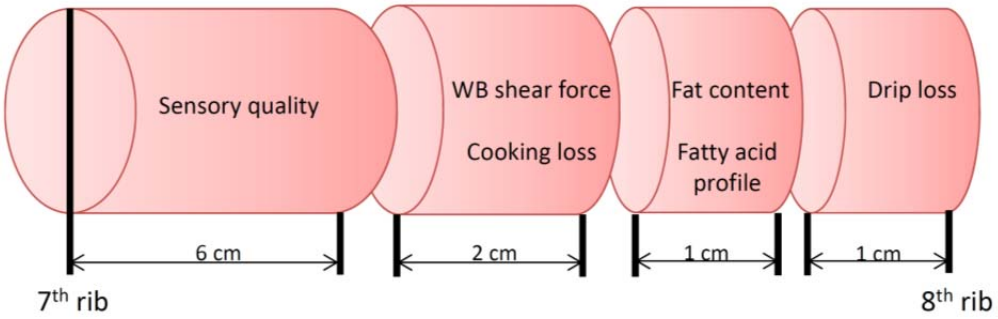

Figure 1: The location of each sample in the *Longissimus dorsi*

In the same day when dissection was performed, *Longissimus dorsi* muscle starting at the 7th rib was removed and its samples were used for the meat quality analysis (Figure 1). A sample for sensory quality determination represented 6 cm thick steak, immediately vacuum-packed, aged at 4°C for 10 days *post-mortem* and then frozen (-20°C) until analysis. A sample for Warner-Bratzler shear force as well as cooking loss determination represented 2 cm thick stake, vacuum-packed, aged at 4°C for 10 days *post-mortem* and then frozen (-20°C) until analysis. A sample for fat content and fatty acid profile determination represented 1 cm thick steak (70 g) without connective tissue epimysium, vacuum-packed and immediately frozen (-20°C) until analysis. Samples for drip loss recording represented a 70 g steak 1 cm thick hanged in a plastic bag.

Analytical methods

Sensory quality

Sensory analysis was performed on 10 days aged stakes (3 cm thick samples) from *Longissimus dorsi* thawed overnight at 4 – 5°C. Stakes were grilled on the pre-heated double hot-plate grill at 200°C until the internal temperature reached 60°C. Sample internal temperature was monitored using a thermocouple probe inserted in the stake midpoint. The core portion of the stakes were cut on pieces of 2 x 2 x 1 cm and were offered to four panellists. Four panellists were asked to assess meat colour in the raw stakes as well as tenderness, juiciness, texture in mouth and flavour of grilled samples on a 7-point scale, with the intensity increasing from 1 to 7. Additionally, each panellist assessed the same steak-location subsample in order to minimise any steak-location effects.

Cooking loss

Samples were represented by ten days aged 2 cm thick stakes from *Longissimus dorsi.* They were thawed for 24 h at 5°C and weighed. Stakes were put in a thin-walled plastic bags and placed in a continuously boiling temperature-controlled water-bath (80°C) with the bag opening extending above the water surface. Samples were cooked when they attained an internal temperature of 70°C recorded by thermometer. They were removed from the water-bath, cooled in an ice water and held in chill conditions. Then they were taken from the bag, blotted dry and weighed. Cooking loss was estimated as the weight-difference between initial and cooked stakes and is expressed as the percentage of the initial sample weight (Honikel, 1998).

Warner-Bratzler shear force

Warner-Bratzler shear force (N) was measured on ten square cores (1.00 cm^2 area) removed parallel to the muscle fibre direction from ten days aged, cooked and cooled *Longissimus dorsi* steak sample. Square cores were removed by taking five 1.00 cm strips from the steak. Each strip was then cut to obtain two square cores of 1.00 cm^2 area. Then cores were sheared once perpendicular to the long axis of the fibres using an Instron Universal Testing machine (Model 3345, Instron, Canton, MA), equipped with a Warner-Bratzler shear device. The Instron unit was calibrated to a full scale using a 500 Newton load cell, a crosshead speed of a 250 millimetres/minute, and a sample rate of 10 points/second. The mean value of the replicate determinations of the maximum force needed to shear ten square cores was taken as the shear force value.

Drip loss after 2 and 6 days

Drip loss was measured according to bag method. A slice of meat from *Longissimus dorsi* (1 cm thick and approximately 80 – 100 g weight) was hung in a plastic bag. It was ensured that the sample was not in contact with the bag. After a storage period of 2 days at chill temperature (4ºC) the sample was weighed again and again, after 6 days of storage. Drip loss was calculated as the difference in weight before and after hanging (2^{nd} and 6^{th} day) and expressed as a percentage of initial weight (Honikel, 1998; Barton-Gade et al., 1994).

Fat and fatty acid composition

Each sample was defrosted and ground to homogeneous consistency using a food processor. Crude intramuscular fat content was determined using petroleum ether extraction after hydrolysis of sample in 4 M HCl solution according to manufacturer's application note (Foss, Application note AN 3904). Total fat determination includes acid hydrolysis step, in which fat bound polar components are separated and later extracted. In this case, samples were hydrolysed in 4 M HCl in SoxCap 2047 (Soxtec 2050, Foss system, Höganäs, Sweden). After drying, fat from hydrolysed samples was extracted using petroleum ether in Soxtec 2050 (Foss system, Höganäs, Sweden).

Fatty acid methyl esters were prepared according to Park and Goins (1994) using *in-situ* trans-esterification method and analysed using gas chromatograph (6890 series, Agilent, Santa Clara, CA, USA). Fatty acid methyl esters were separated using a capillary column (Varian CP 4720, length 100 m, internal diameter 250 μm, film thickness 0.25 μm). Agilent GC ChemStation was used for data acquisition and processing. Separated fatty acid methyl esters were identified by retention time comparison and results were calculated using response factors derived from the chromatographic standards of known fatty acid composition (Nu Chek Prep). The exactness and reliability of the method used was assessed with the certified reference material NIST SRM 1546 Meat Homogenate. Fatty acid composition was expressed as the percentage of total identified fatty acids (wt.%).

Statistical analysis

Carcass and meat traits were analysed with the statistical package SAS/STAT (SAS Institute Inc., 2001) using a GLM procedure, considering breed and diet as fixed effects (Model 1). Fatty acids composition was analysed by a GLM procedure considering breed, diet and breed × diet interaction as fixed effects (Model 2).

RESULTS AND DISCUSSION

At the beginning of Cika cattle conservation and at time when breeding program was established, the population size was too low to arrange any fattening trial with young bulls in comparable environmental conditions. Only the slaughter data from the commercial slaughter houses existed for all categories of Cika cattle. Consequently, Simčič et al. (2008) and Simčič et al. (2011) reported carcass weight, as well as conformation and fatness scores of slaughtered Cika cattle. However, enormous variability among records was found due to very different fattening technologies. Low carcass weight (266.7 kg), poor conformation (6.4) and fatness (5.8) low scores on the 1 – 15 points scale of young bulls (Simčič et al., 2011) made bad recommendations for rearing and fattening bulls of Cika breed. Lately, when the population size increased a few fattening trials were carried out and the results of growth performance and carcass quality of Cika young bulls were published (Žgur et al., 2014), but where meat quality has not been completely considered yet.

Young bulls of Cika were fattened with two different diets and Simmental bulls in the same conditions were used like a reference breed because Simmental is the most widespread and fattened breed in Slovenia. Cika bulls achieved non-significantly lower carcass weight (332.64 ± 6.63 kg) compared to Simmental (348.72 ± 6.63 kg) (Table 2). Young Simmental bulls included to feeding regime by which Cika young bulls are commonly fattened did not show their growth and production potential, what should be explained with low energy content in the EXT and S-INT diet. On the other hand, dressing percentage was significantly higher in Cika (55.79 ± 0.35%) compared to Simmental young bulls (54.42 ± 0.35%). Carcass morphological measurements showed shorter carcass length of Cika (135.11 ± 0.64 cm) compared to Simmental young bulls (138.03 ± 0.64 cm). However, there was no difference between young bulls of both breeds in chest depth and conformation index (Table 2).

Čepin et al. (1988) reported carcass and meat quality of Simmental bulls reared in very similar conditions and fed similar S-INT diet. In fact, they found lower carcass weight (327 kg), similar dressing percentage (54.96%) and conformation index (56.28) compared to Simmental bulls from this study (348.72 kg, 54.42%, 56.63), respectively. Zapletal et al. (2009) found higher carcass weight and similar dressing percentage in Czech Fleckvieh (360.4 kg, 54.1%) and Montbeliarde young bulls (388.6 kg, 55.0%) fattened in Moravia and slaughtered one month earlier.

Regarding the effect of the diet (semi-intensive *vs.* extensive total mixed ratio) there were significant difference between S-INT and EXT fed bulls (Table 2) in carcass weight (360.80 ± 6.63 kg; 320.58 ± 6.63 kg), dressing percentage (55.88 ± 0.35%; 54.33 ± 0.35%), carcass length (138.98 ± 0.64 cm; 134.16 ± 0.64 cm) and conformation index (58.59 ± 0.98; 54.48 ± 0.98), respectively. On the other hand, Marino et al. (2006) reported no differences in carcass traits (slaughter weight, carcass weight, weights of the main cuts, and dressing percentage) of Podolian bulls fed with high (forage to concentrate ratio 60:40) and low concentrate feed (forage to concentrate ratio 70:30).

Table 2. Carcass and meat traits of Cika and Simmental young bulls from different diets

Trait	Breed (LSM ± SE)		Diet (LSM ± SE)		p-values		R^2
	Cika	Simmental	S-INT	EXT	Breed	Diet	
Carcass weight (kg)	332.64 ± 6.63	348.72 ± 6.63	360.80 ± 6.63	320.58 ± 6.63	n.s.	0.001	0.37
Dressing percentage (%)	55.79 ± 0.35	54.42 ± 0.35	55.88 ± 0.35	54.33 ± 0.35	0.010	0.004	0.32
Carcass length (cm)	135.11 ± 0.64	138.03 ± 0.64	138.98 ± 0.64	134.16 ± 0.64	0.003	< 0.001	0.51
Chest depth (cm)	43.60 ± 0.36	44.57 ± 0.36	44.30 ± 0.36	43.87 ± 0.36	n.s.	n.s.	0.11
Conformation index	56.45 ± 0.98	56.63 ± 0.98	58.59 ± 0.98	54.48 ± 0.98	n.s.	0.005	0.19
L*	35.63 ± 0.36	35.86 ± 0.36	35.93 ± 0.36	35.56 ± 0.36	n.s.	n.s.	0.02
a*	24.98 ± 0.58	21.55 ± 0.58	23.69 ± 0.58	22.84 ± 0.58	0.002	n.s.	0.33
b*	11.56 ± 0.35	9.83 ± 0.35	10.90 ± 0.35	10.49 ± 0.35	0.001	n.s.	0.26
pH (24 h)	5.57 ± 0.03	5.80 ± 0.03	5.66 ± 0.03	5.70 ± 0.03	< 0.001	n.s.	0.45
Electrical conductivity	8.78 ± 0.50	8.49 ± 0.50	9.79 ± 0.50	7.48 ± 0.50	n.s.	0.003	0.22
Visual marbling (points 1 – 9)	2.25 ± 0.15	1.95 ± 0.15	2.05 ± 0.15	2.15 ± 0.15	n.s.	n.s.	0.06

LSM – least square mean, SE – standard error, R^2 – coefficient of determination, S-INT – semi intensive total mixed ratio, EXT – extensive total mixed ratio, n.s. – not significant

The colour of fresh meat is one of the most important parameters for consumers. In this study, Cika and Simmental young bulls had similar meat lightness (L*) (35.63 ± 0.36; 35.86 ± 0.36), respectively. On the other hand, meat of Cika bulls had significantly higher redness (a* = 24.98 ± 0.58) and yellowness (b* = 11.56 ± 0.35) than meat of Simmental young bulls (a* = 21.55 ± 0.58; b* = 9.83 ± 0.35), respectively.

Čepin et al. (1988) and Zgubič et al. (1999) recorded meat colour of Simmental and Brown bulls finished in similar rearing conditions like S-INT fed bulls in this study. Simmental and Brown bulls had lighter (L* = 36.02; L* = 38.53), less red (a* = 20.53; a* = 21.07) and more yellow (b* = 10.05; b* = 11.61) meat compared to Simmental bulls in this study, respectively. However, Belgian Blue (a* = 20.7) and Limousin (a* = 21.7) bulls (Raes et al., 2003) had less red meat compared to our Cika and Simmental bulls. Among the studied indigenous breeds, Liotta et al. (2011) found lighter (L* = 44.90 ± 1.70), less red (a* = 18.03 ± 2.23) and more yellow (b* = 15.39 ± 1.69) meat of indigenous Cinisara young bulls from Sicily compared to Cika bulls. Sargentini et al. (2010) found lighter (L* = 40.70), less red (a* = 22.00) and less yellow (8.68) meat of Maremmana young bulls, and Beriain et al. (2009) found lighter (L* = 38.04), less red (a* = 14.8) and less yellow (b* = 10.2) meat of indigenous Pirenaica young bulls from Navarra in Spain compared to Cika bulls. Marino et al. (2006) found a difference only in the yellowness in meat colour of Podolian bulls fed low (L* = 36.6, a* = 19.09, b* = 4.05) and high (L* = 35.13, a* = 20.11, b* = 4.28) concentrate to forage ratio diet. There was a significant difference in pH value 24h after slaughter between Cika (5.57 ± 0.03) and Simmental (5.80 ± 0.03) bulls. It slightly elevated in Simmental breed, though the pH value 24h after slaughter was lower than 6.00 in meat of both breeds and both diets. Higher pH is usually taken as an indicator of dark-cutting beef.

Despite the electrical conductivity is used mainly as the indicator of pork quality (Shirsat et al., 2004) it can be used also in beef. Meat has a sizeable amount of water and dissolved salts what makes it electrically conductive. Higher conductivity values for lean meat in relation to fat was due to the presence of higher level of moisture and salt content in lean meat. However, there was no difference in the conductivity between Cika and Simmental beef, while the diet significantly affected electrical conductivity. S-INT fed bulls had higher electrical conductivity (9.79 ± 0.50) than EXT fed bulls (7.48 ± 0.50). However, higher fat content in pork was the reason for lower conductivity (Shirsat et al., 2004). On the other hand, Sarang et al. (2008) reported that in the lean beef it was difficult to find any relationship between the electrical conductivity and determined intramuscular fat content. In many countries, the degree of marbling is considered the major factor in determining beef "quality grade" (Indurian et al., 2009). Here, marbling was very similar in carcasses of both breeds in both diets, the differences were not significant.

Carcass composition is an important factor in the evaluation of carcass quality. Carcass tissue proportion for Cika and Simmental young bulls is presented in Table 3. The dissection of the whole right carcass sides gave 73.66 ± 0.37% of lean meat, 9.51 ± 0.36% of total fat (2.01 ± 0.10% subcutaneous fat, 7.50 ± 0.29% intermuscular fat), 1.48 ± 0.05% of tendons and 15.35 ± 0.21% of bones in Cika carcasses, while 73.37 ± 0.37% of lean meat, 8.20 ± 0.36% of total fat (1.68 ± 0.10% subcutaneous fat, 6.52 ± 0.29% intermuscular fat), 1.81 ± 0.05% of tendons and 16.63 ± 0.21% of bones in Simmental carcasses. Considering all tissue proportions, Cika young bulls had significantly more total fat, less tendons and less bones in carcasses compared to Simmental. The lower fat proportion in carcasses of Simmental bulls could be explained with the lower slaughter age and achieved lower proportion of adult size. Likewise, when total fat was separated on subcutaneous and intermuscular fat Cika bulls had significantly more subcutaneous (2.01 ± 0.10%), as well as intermuscular (7.50 ± 0.29%) fat compared to Simmental young bulls (1.68 ± 0.10%, 6.52 ± 0.29%), respectively. The subcutaneous fat represented 21.00 ± 0.71% (Cika) and 20.68 ± 0.71% (Simmental) of total fat. The difference between breeds was not significant. It is widely known that British beef breeds have higher percentage of subcutaneous fat, while dairy breeds deposit more fat like kidney and channel fat. Žgur and Čepon (2007) investigated the distribution of total fat in carcasses of slightly younger bulls of Simmental and Brown dual-purpose breeds from very similar rearing conditions as S-INT fed bulls. They found no differences in the distribution of subcutaneous and intermuscular fat between breeds. However, the percentage of subcutaneous fat in total fat content was higher in Simmental (27.41%) and Brown (26.40%) bulls (Žgur and Čepon, 2007) compared to bulls in this study. If we consider the fact that early matured animals had more developed subcutaneous fat at the same age or weight, then the higher proportion of it in Cika compared to Simmental could be explained with higher maturity of Cika bulls.

The lean meat to bones ratio in Cika carcasses (Table 3) was significantly higher (4.82 ± 0.07) compared to Simmental carcasses (4.43 ± 0.07). On the other hand, Simmental carcasses had significantly higher lean meat to total fat ratio (9.23 ± 0.38) compared to Cika carcasses (8.07 ± 0.38). The effect of the diet was significant in bones proportion and lean meat to bones ratio. S-INT fed bulls has lower bones proportion (15.58 ± 0.21%) and higher lean meat to bones ratio (4.74 ± 0.07) compared to EXT feed bulls (16.40 ± 0.21%; 4.51 ± 0.07), respectively.

Čepin et al. (1988) reported carcass composition of Simmental bulls from similar rearing conditions. In the carcasses of Simmental young bulls there was less lean meat (70.09%), more fat (11.76%), and similar bones (16.37%), as well as tendons (1.63%) proportion compared to Simmental bulls from this study.

Compared to carcasses composition in others indigenous breeds, Cika and Simmental bulls were the most similar to Gasconne young bulls (73.9% lean meat, 14.5% bones, 2.2% subcutaneous fat, 7.8% intermuscular fat) from France (Piedrafita et al., 2003), and to Spanish local Pirenaica bulls in the proportions of lean meat (72.9%), total fat (9.7%,) and bones (17.5%) (Albertí et al., 2008). Among Portuguese breeds, the most similar carcass composition had Mertolenga young bulls, with 70.0% of lean meat, 15.4% of bones and a little higher total fat (15.4%) (Simões and Mendes, 2003).

Table 3. Carcass composition and *Longissimus dorsi* area in Cika and Simmental young bulls from different diets

Trait	Breed (LSM ± SE)		Diet (LSM ± SE)		p-values		R^2
	Cika	Simmental	S-INT	EXT	Breed	Diet	
Lean meat (%)	73.66 ± 0.37	73.37 ± 0.37	73.48 ± 0.37	73.55 ± 0.37	n.s.	n.s.	0.01
Total fat (%)	9.51 ± 0.36	8.20 ± 0.36	9.32 ± 0.36	8.39 ± 0.36	0.015	n.s.	0.21
Tendons (%)	1.48 ± 0.05	1.81 ± 0.05	1.61 ± 0.05	1.67 ± 0.05	< 0.001	n.s.	0.39
Bones (%)	15.35 ± 0.21	16.63 ± 0.21	15.58 ± 0.21	16.40 ± 0.21	0.001	0.009	0.41
Subcutaneous fat (%)	2.01 ± 0.10	1.68 ± 0.10	1.93 ± 0.10	1.76 ± 0.10	0.023	n.s.	0.16
Intermuscular fat (%)	7.50 ± 0.29	6.52 ± 0.29	7.40 ± 0.29	6.62 ± 0.29	0.021	n.s.	0.20
Subcutaneous fat/total fat (%)	21.00 ± 0.71	20.68 ± 0.71	20.56 ± 0.71	21.12 ± 0.71	n.s.	n.s.	0.01
Lean meat : bones ratio	4.82 ± 0.07	4.43 ± 0.07	4.74 ± 0.07	4.51 ± 0.07	0.001	0.029	0.35
Lean meat : total fat ratio	8.07 ± 0.38	9.23 ± 0.38	8.24 ± 0.38	9.06 ± 0.38	0.040	n.s.	0.16
Longissimus dorsi area (cm^2)	55.59 ± 1.33	57.10 ± 1.33	59.96 ± 1.33	52.73 ± 1.33	n.s.	0.001	0.29

LSM – least square mean, SE – standard error, R^2 – coefficient of determination, S-INT – semi intensive total mixed ratio, EXT – extensive total mixed ratio, n.s. – not significant

There was no difference in the *Longissimus dorsi* area in the level between 6^{th} and 7^{th} rib between Cika (55.59 ± 1.33 cm^2) and Simmental (57.10 ± 1.33 cm^2) young bulls' carcasses (Table 3). On the other hand, the effect of the diet was significant in S-INT fattened bulls (59.96 ± 1.33 cm^2) with larger *Longissimus dorsi* area compared to EXT fattened (52.73 ±

1.33 cm^2) young bulls. The *Longissimus dorsi* area of Cika was similar to Gasconne (55.1 cm^2) young bulls (Piedrafita et al., 2003).

Sensory analysis included meat colour determined on the defrosted stakes, as well as tenderness, juiciness, texture in mouth and flavour determined on grilled steaks sampled from *Longissimus dorsi* which were aged for ten days (Table 4). The effect of the breed was significant just in flavour intensity, where Cika bulls had more flavoured beef (5.39 ± 0.11) compared to Simmental bulls (5.09 ± 0.12). Though Cika beef (5.56 ± 0.16) was slightly more tender compared to Simmental beef (5.17 ± 0.18) what corresponds with Warner-Bratzler shear force, a slightly higher force was applied in Simmental (49.32 ± 3.92 N) compared to Cika beef (43.16 ± 3.91 N), the differences were not statistically significant. Similar shear force found Keane and Allen (1998) in the meat of extensively fattened steers (40.3 N) of Charolais x Friesian breed. Meat belonging to Simmental young bulls was also less tender in the sensory analysis in the study of Čepin et al. (1988), where Simmental (3.70), Brown (4.64), Black and White (4.85) and crossbred young bulls (5.43) were included.

The differences in sensory quality between 10 days aged Simmental meat from this study and 14 days aged Simmental meat (Lebarič et al., 2011) were very low (tenderness 5.17 *vs*. 4.7, juiciness 5.42 *vs.* 5.9, flavour 5.09 *vs.* 5.6), while the difference in Warner-Bratzler shear force was higher (49.32 N *vs.* 37.4 N). Lebarič et al. (2011) described suitable sensory quality for loin (*Longissimus dorsi)* when all included parameters (meat colour, tenderness, juiciness, flavour) are scored with scores more than five. Considering this rule, Simmental meat as well as meat of indigenous Cika young bulls from this study was appropriate regarding sensory quality expected by consumers. The diet did not significantly affected sensory quality parameters, what is not in accordance with Resconi et al. (2010) who found flavour intensity in the meat of Uruguayan Hereford steers negatively correlated/associated with the diet energy content.

The cooking loss was determined on ten days aged samples taken from *Longissimus dorsi* (Table 4). The cooking loss was similar in Cika (20.81 ± 1.21%) compared to Simmental bulls (20.10 ± 1.21%). On the other hand, cooking loss determined in *Longissimus dorsi* of Cinisara bulls (Liotta et al., 2011) was almost 4% higher (24.44 ± 7.56%).

Table 4. Sensory quality, shear force, cooking and drip loss in the meat of Cika and Simmental young bulls from different diets

Trait	Breed (LSM ± SE)		Diet (LSM ± SE)		p-values		R^2
	Cika	Simmental	S-INT	EXT	Breed	Diet	
Meat colour (points 1 – 7*)	5.05 ± 0.15	5.26 ± 0.16	5.13 ± 0.15	5.17 ± 0.15	n.s.	n.s.	0.03
Tenderness (points 1 – 7*)	5.56 ± 0.16	5.17 ± 0.18	5.35 ± 0.17	5.38 ± 0.17	n.s.	n.s.	0.08
Juiciness (points 1 – 7*)	5.49 ± 0.06	5.42 ± 0.07	5.40 ± 0.06	5.50 ± 0.06	n.s.	n.s.	0.06
Texture in mouth (points 1 – 7*)	5.32 ± 0.07	5.17 ± 0.08	5.22 ± 0.07	5.28 ± 0.07	n.s.	n.s.	0.07
Flavour (points 1 – 7*)	5.39 ± 0.11	5.09 ± 0.12	5.21 ± 0.11	5.24 ± 0.11	0.042	n.s.	0.12
Warner-Bratzler shear force (N)	43.16 ± 3.91	49.32 ± 3.92	48.19 ± 3.91	44.28 ± 3.91	n.s.	n.s.	0.04
Cooking loss (%)	20.81 ± 1.21	20.10 ± 1.21	20.72 ± 1.12	20.18 ± 1.12	n.s.	n.s.	0.01
Drip loss, after 2 days (%)	0.92 ± 0.05	0.66 ± 0.05	0.84 ± 0.05	0.75 ± 0.05	0.002	n.s.	0.26
Drip loss, after 6 days (%)	2.79 ± 0.19	1.75 ± 0.19	2.39 ± 0.19	2.15 ± 0.19	0.001	n.s.	0.30

LSM – least square mean, SE – standard error, R^2 – coefficient of determination, S-INT – semi intensive total mixed ratio, EXT – extensive total mixed ratio, n.s. – not significant, *1 – extremely bland, 7 – extremely intense

The drip loss (Table 4) of *Longissimus dorsi* samples after 2 days hanging were significantly higher in Cika (0.92 ± 0.05%) compared to Simmental samples (0.66 ± 0.05%). The difference in drip loss of *Longissimus dorsi* increased after six days when was 2.79 ± 0.19% in Cika and 1.75 ± 0.19% in Simmental samples. However, the effect of the diet was not significant for drip as well as for cooking loss. Likewise, Keane and Allen (1998) found no difference in the drip loss after four days in the meat of intensively (2.38%) fattened bulls, and conventionally (2.37%) as well as extensively (2.20%) fattened steers of Charolais x Friesian breeds.

Cooking loss of young bull's *Longissimus dorsi* samples of indigenous Cika (20.81 ± 1.21%) and Simmental (20.10 ± 1.21%) was similar to cooking loss of young bulls of indigenous Bruna del Pirineus (22.91%), Avileña-Negra Ibérica (23.40%) and Morucha from Spain (24.62%) (Serra et al., 2008). There were no significant differences in the cooking loss between Cika and Simmental breeds and between diets.

In many countries, fat is an unpopular constituent of meat for consumers, being considered unhealthy. Yet, fat and fatty acids contribute importantly to various aspects of meat quality and are central to the nutritional value of meat (Wood et al., 2008). In this study, total intramuscular fat content (Table 5) was significantly higher in Cika beef (24.06 ± 1.95 g/kg) compared to Simmental (13.02 ± 1.95 g/kg) what could be explained with higher carcass fat percentage in Cika bulls. On the other hand, Sargentini et al. (2010) found even less intramuscular fat (0.75%) in the beef of 24 months old Maremmana bulls. Likewise, Marino et al. (2006) reported no differences in the intramuscular fat content of Podolian bulls fed with high (forage to concentrate ratio 60:40) and low concentrate feed (forage to concentrate ratio 70:30). Intramuscular fat content increases with animal's age and live weight and affects also its fatty acid composition (Wood et al., 2008).

Consequently, Cika beef contained significantly more SFA (48.61 ± 0.36 wt.%) and less PUFA (12.65 ± 1.10 wt.%) compared to Simmental (45.28 ± 0.36 wt.%; 18.28 ± 1.10 wt.%), respectively. The MUFA content in beef from both breeds was very similar (Cika = 38.74 ± 1.10 wt.%, Simmental = 36.44 ± 1.10 wt.%). However, the diet did not significantly affect the percentage of SFA, MUFA, PUFA in the beef from both breeds.

Sargentini et al. (2010) found less SFA (41.98 wt.%), less MUFA (32.74 wt.%) and higher percent of PUFA (25.29 wt.%) in the beef of 24 months old Maremmana bulls fed on pastures supplemented with mixed hay *ad libitum* and concentrates. Marino et al. (2006) investigated the effect of different forage to concentrate ratio on SFA, MUFA and PUFA in the beef of Podolian bulls. In the beef of bulls fed with low concentrate ratio there was less SFA (44.41 wt.%) and MUFA (28.86 wt.%), as well as more PUFA (26.73 wt.%) compared to high concentrate diet fed bulls (46.50 wt.%, 34.10 wt.%, 19.23 wt.%), respectively. De la Fuente et al. (2009) determined fatty acid composition in the beef of Fleckvieh x Limousin crossbred bulls, finished on the corn silage *ad libitum* with restricted soy and cereal meal. They found 45.60 wt.% SFA, 46.90 wt.% MUFA and 7.50 wt.% PUFA. Corazzin et al. (2012) determined neutral lipids fatty acid composition in the meat of Simmental and Holstein bulls. Simmental meat contained more SFA (57.14 wt.%) and MUFA (38.48 wt.%) and consequently less PUFA (4.38 wt.%) compared to Holstein beef (54.51 wt.%, 36.81 wt.%, 8.68 wt.%), respectively.

However, beef of Cika and Simmental bulls in this study compared to beef of Fleckvieh x Limousin bulls (De la Fuente et al., 2009), as well as Simmental and Holstein bulls (Corazzin et al., 2012) contained considerably less intramuscular fat, as well as similar SFA, lesser MUFA and much higher PUFA proportion. The reason for the difference could be in low intramuscular fat content in the lean meat and consequently high proportion of phospholipid content in the total lipid content. A significant proportion of fat in muscles are phospholipids which have much higher PUFA content in order to perform muscle function as a constituent of cellular membranes (Wood et al., 2008).

Raes et al. (2003) found 21.7 wt.% of PUFA in double muscling Belgian Blue beef which contained 8.6 mg/g intramuscular fat whereas Irish beef meat contained 6.93 wt.% of PUFA and 37.1 mg/g intramuscular fat. Likewise, Sargentini et al. (2010) reported the low level of intramuscular fat (0.7%) and high level of PUFA (23.2 wt.%) in the *Longissimus thoracis* muscle of Maremmana bulls.

The relative proportion of n-6PUFA was significantly lower in Cika (10.36 ± 1.00 wt.%) compared to Simmental (15.30 ± 1.00 wt.%), while there was no effect of the diet. Likewise, the relative proportion of n-3PUFA was significantly lower in Cika (1.98 ± 0.13 wt.%) compared to Simmental (2.75 ± 0.13 wt.%). There was also significantly higher proportion of n-3PUFA in the beef of EXT (2.97 ± 0.13 wt.%) fed bulls compared to S-

INT (1.75 ± 0.13 wt.%). Above all, the breed x diet interaction significantly affected n-3PUFA proportions.

Consequently, the n-6/n-3 PUFA ratio was significantly lower in Cika beef (5.35 ± 0.22) compared to Simmental beef (5.99 ± 0.22). There was also seen a significant effect of the diet where S-INT fed bulls had higher n-6/n-3 PUFA ratio (7.03 ± 0.22) compared to EXT fed bulls (4.32 ± 0.22). Lower n-6/n-3 ratio due to higher content of n-3PUFA in Cika and Simmental beef could be a result of grass silage included in the S-INT and EXT diet. Beef from both breeds and diets had the n-6/n-3 ratio inside the recommended values 10:1 (Commission of European Communities, 1993). Very similar n-6/n-3 ratio found Marino et al. (2006) in the beef of Podolian bulls fed high (6.37) and low (6.63) concentrate to forage diet as well as De la Fuente et al. (2009) in the beef of Fleckvieh x Limousin crossbred bulls (7.60) finished on the corn silage and restricted soy and cereal meal.

Considering individual fatty acids, breed significantly affected the percentage of almost all individual fatty acids from SFA and from PUFA groups. The major fatty acid in the meat was oleic acid (C18:1*cis*-9) predominant in neutral lipids, where the difference was not significant between breeds. Oleic acid is formed from stearic acid (C18:0) (Wood et al., 2008) where a significant difference between breeds (Cika = 17.55 ± 0.35 wt.%, Simmental = 15.88 ± 0.35 wt.%) was determined. Higher intramuscular fat content in Cika beef could be the reason for higher stearic percentage in Cika.

All included individual PUFA had higher percentage in the beef of Simmental bulls, with the exception of C18:3 n-6. The proportion of linoleic fatty acid (C18:2 n-6) which is the major PUFA was significantly higher in Simmental (11.10 ± 0.71 wt.%) compared to Cika (8.14 ± 0.71 wt.%) beef (Table 5). Linoleic acid derived from the diet (grains and oilseeds) is exposed to microbial biohydrogenation in the rumen, so only around 10% of dietary linoleic acid is available for the incorporation into tissue lipids. Furthermore, linoleic acid is at much higher proportions in phospholipids than in neutral lipids. In young lean animals, genetically lean or fed a low energy diet, the lower oleic and higher linoleic fatty acid proportion is expected (Wood et al., 2008).

On the other hand, the effect of the diet significantly affected only a few individual fatty acids, where the most important were α-linolenic, EPA, and DPA with higher percentage in the beef of EXT fed bulls. Quite significant was also the interaction between breed and diet (Table 5). α-linolenic acid (C18:3 n-3) is the second most important PUFA with the proportion higher in phospholipid, as well as a major dietary fatty acid for ruminants since it constitutes over 50% of total fatty acids in the grass and grass products. Likewise, a higher proportion is biohydrogenated in the rumen (Wood et al., 2008). There was found significant effect of diet (S-INT = 0.92 ± 0.07 wt.%, EXT = 1.78 ± 0.06 wt.%) and breed x diet interaction on the α-linolenic fatty acid proportion. If we remind, in the EXT feed ratio there was 80% of grass silage.

Two important products formed from linoleic and α-linolenic acid are arachidonic (C20:4 n-6) and EPA (C20:5 n-3) fatty acids (Wood et al., 2008). Similar to linoleic fatty acid, the proportion of arachidonic acid (C20:4 n-6) was significantly higher in Simmental (3.19 ± 0.24 wt.%) compared to Cika (1.61 ± 0.24 wt.%) beef. And similar to α-linolenic acid, a significant effect of breed (Cika = 0.20 ± 0.02 wt.%, Simmental = 0.40 ± 0.02 wt.%), diet (S-INT = 0.23 ± 0.02 wt.%, EXT = 0.37 ± 0.02 wt.%) and their interaction on the EPA (C20:5 n-3) fatty acid proportion was found (Table 5).

In ruminants, as a result of biohydrogenation in the rumen, a significant proportion of double bonds are of the *trans* type and these fatty acids have particularly low melting points. One of them is conjugated linoleic acid (CLA, C18:2*cis*-9, *trans*-11). Like C18:1*cis*-9 also CLA are at higher proportions in neutral lipid than phospholipid and higher in adipose tissue than in a muscle. CLA has health benefits in the human diet (Wood et al., 2008). Consequently, Cika beef contained more conjugated linoleic acid (CLA) (0.30 ± 0.01 wt.%) compared to Simmental (0.26 ± 0.01 wt.%) what could be partly explained by the higher intramuscular fat content in Cika beef, since it is well known that the CLA content of meat increases with fatness.

Table 5. Intramuscular fat content and fatty acid composition in beef of Cika and Simmental young bulls from different diets

Trait	Breed (LSM ± SE)		Diet (LSM ± SE)		p-values			R^2
	Cika	Simmental	S-INT	EXT	Breed (B)	Diet (D)	B x D	
Intramuscular fat (g/kg)	24.06 ± 1.95	13.02 ± 1.95	19.70 ± 1.95	17.38 ± 1.95	0.001	n.s.	n.s.	0.32
Fatty acid (wt. %)								
C12:0 (Lauric)	0.07 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.010	n.s.	n.s.	0.17
C13:1 n-1	0.06 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.001	n.s.	n.s.	0.26
C14:0 (Myristic)	2.37 ± 0.11	1.69 ± 0.11	2.04 ± 0.11	2.02 ± 0.11	0.001	n.s.	n.s.	0.35
C14:1 n-5	0.38 ± 0.04	0.42 ± 0.04	0.43 ± 0.04	0.36 ± 0.04	n.s.	n.s.	n.s.	0.10
C15:0 iso	0.17 ± 0.01	0.15 ± 0.01	0.15 ± 0.01	0.17 ± 0.01	0.012	n.s.	n.s.	0.24
C15:0 aiso	0.22 ± 0.01	0.23 ± 0.01	0.21 ± 0.01	0.24 ± 0.01	n.s.	0.002	0.018	0.33
C15:0	0.40 ± 0.01	0.39 ± 0.01	0.36 ± 0.01	0.43 ± 0.01	n.s.	0.001	n.s.	0.34
C15:1 n-5	0.24 ± 0.03	0.42 ± 0.03	0.30 ± 0.03	0.35 ± 0.03	0.001	n.s.	n.s.	0.31
C16:0 iso	0.20 ± 0.01	0.19 ± 0.01	0.20 ± 0.01	0.19 ± 0.01	n.s.	n.s.	n.s.	0.01
C16:0 aiso	1.60 ± 0.14	2.28 ± 0.14	1.80 ± 0.14	2.08 ± 0.14	0.002	n.s.	n.s.	0.27
C16:0 (Palmitic)	22.42 ± 0.49	20.20 ± 0.49	21.58 ± 0.49	21.04 ± 0.49	0.003	n.s.	n.s.	0.23
C16:1 n-7	2.70 ± 0.14	2.89 ± 0.14	2.88 ± 0.14	2.71 ± 0.14	n.s.	n.s.	n.s.	0.05
C17:0 iso	0.37 ± 0.01	0.41 ± 0.01	0.37 ± 0.01	0.41 ± 0.01	0.001	0.002	n.s.	0.41
C17:0 aiso	0.49 ± 0.01	0.49 ± 0.01	0.48 ± 0.01	0.50 ± 0.01	n.s.	n.s.	n.s.	0.05
C17:0 (Margaric)	0.84 ± 0.02	0.80 ± 0.02	0.77 ± 0.01	0.86 ± 0.01	n.s.	0.002	n.s.	0.28
C17:1 n-7	0.55 ± 0.02	0.60 ± 0.02	0.53 ± 0.02	0.62 ± 0.02	n.s.	0.010	n.s.	0.21
C18:0 (Stearic)	17.55 ± 0.35	15.88 ± 0.35	16.64 ± 0.35	16.80 ± 0.35	0.002	n.s.	n.s.	0.26
C18:0 iso	0.15 ± 0.01	0.17 ± 0.01	0.16 ± 0.01	0.16 ± 0.01	0.002	n.s.	n.s.	0.24
C18:0 aiso	1.57 ± 0.17	2.23 ± 0.17	1.77 ± 0.17	2.03 ± 0.17	0.010	n.s.	n.s.	0.20
C18:1 (Oleic)	34.51 ± 0.97	31.79 ± 0.97	34.07 ± 0.97	32.22 ± 0.97	n.s.	n.s.	n.s.	0.17
C18:2 n-6 (Linoleic)	8.14 ± 0.71	11.10 ± 0.71	9.51 ± 0.71	9.73 ± 0.71	0.006	n.s.	n.s.	0.19
C18:3 n-6	0.10 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.10 ± 0.01	0.001	0.008	n.s.	0.43
C18:3 n-3 (α-linolenic)	1.26 ± 0.07	1.44 ± 0.07	0.92 ± 0.07	1.78 ± 0.07	n.s.	< 0.001	0.021	0.72
C18:2*cis*-9,*trans*-11 (CLA)	0.30 ± 0.01	0.26 ± 0.01	0.27 ± 0.01	0.25 ± 0.01	0.002	n.s.	n.s.	0.37
C20:0	0.12 ± 0.01	0.12 ± 0.01	0.12 ± 0.01	0.12 ± 0.01	n.s.	n.s.	n.s.	0.14
C20:1 n-12 + C20:1 n-15	0.13 ± 0.01	0.12 ± 0.01	0.13 ± 0.01	0.12 ± 0.01	n.s.	n.s.	n.s.	0.09
C20:1 n-9	0.11 ± 0.01	0.11 ± 0.01	0.12 ± 0.01	0.10 ± 0.01	n.s.	0.016	0.029	0.25
C20:2 n-6	0.07 ± 0.01	0.11 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	0.001	n.s.	n.s.	0.29
C20:3 n-6 (Dihomo-γ-linoleic)	0.31 ± 0.04	0.58 ± 0.04	0.44 ± 0.04	0.45 ± 0.04	< 0.001	n.s.	n.s.	0.40
C20:4 n-6 (Arachidonic)	1.61 ± 0.24	3.19 ± 0.24	2.33 ± 0.24	2.46 ± 0.24	< 0.001	n.s.	n.s.	0.39
C20:5 n-3 (EPA)	0.20 ± 0.02	0.40 ± 0.02	0.23 ± 0.02	0.37 ± 0.02	< 0.001	< 0.001	0.028	0.63
C22:4 n-6 (Ardenic)	0.13 ± 0.02	0.25 ± 0.02	0.20 ± 0.02	0.18 ± 0.02	0.001	n.s.	n.s.	0.35
C22:5 n-3 (DPA)	0.44 ± 0.04	0.79 ± 0.04	0.53 ± 0.04	0.71 ± 0.04	< 0.001	0.006	0.044	0.57
C22:6 n-3 (DHA)	0.04 ± 0.01	0.09 ± 0.01	0.06 ± 0.01	0.08 ± 0.01	< 0.001	n.s.	0.038	0.60
C24:1 n-9	0.05 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	n.s.	n.s.	n.s.	0.11
SFA	48.61 ± 0.36	45.28 ± 0.36	46.74 ± 0.36	47.14 ± 0.36	< 0.001	n.s.	0.040.	0.57
MUFA	38.74 ± 1.10	36.44 ± 1.10	38.57 ± 1.10	36.61 ± 1.10	n.s.	n.s.	n.s.	0.13
PUFA	12.65 ± 1.10	18.28 ± 1.10	14.68 ± 1.10	16.25 ± 1.10	0.001	n.s.	n.s.	0.29
n-3PUFA	1.98 ± 0.13	2.75 ± 0.13	1.75 ± 0.13	2.97 ± 0.13	0.001	< 0.001	0.018	0.66
n-6PUFA	10.36 ± 1.00	15.30 ± 1.00	12.66 ± 1.00	13.01 ± 1.00	0.001	n.s.	n.s.	0.27
n-6/n-3 PUFA ratio	5.35 ± 0.22	5.99 ± 0.22	7.03 ± 0.22	4.32 ± 0.22	0.042	< 0.001	n.s.	0.71

LSM – least square mean, SE – standard error, R^2 – coefficient of determination, S-INT – semi intensive total mixed ratio, EXT – extensive total mixed ratio, n.s. – not significant, CLA – conjugated linoleic acid, EPA – eicosapentaenoic acid, DPA – docosapentaenoic acid, DHA – docosahexaenoic acid, SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids

CONCLUSIONS

The findings from this study show that Cika young bulls, reared in the traditional extensive production system can provide meat of good quality. Physical and chemical characteristics of meat seem to be comparable to meat of young bulls of Simmental cattle and some other indigenous breeds in Europe which have already found a "local niche" for their products. Cika breeders should be encouraged to produce fattened Cika bulls on the farms of their origin. The moderate total fat proportion in dissected carcass sides provides another encouragement for breeders to fatten bulls to higher weights, while still maintaining good carcass and meat quality.

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3 RAZPRAVA IN SKLEPI

3.1 RAZPRAVA

Geografska lega Slovenije je med Alpami in Dinarskim gorovjem Balkana ter med Sredozemljem in Panonsko kotlino. Danes vemo, da je prav za vsako izmed naštetih območij, značilno po zunanjosti drugačno govedo. Gledano nekoliko širše, leži Slovenija med Bližnjim vzhodom (Plodni Polmesec), kjer je bilo pred 10.500 leti udomačeno evropsko govedo in severozahodno Evropo, kjer so pred nedavnim vzredili najbolj specializirane pasme za prirejo mleka ali mesa. Udomačeno govedo se je iz Azije v Evropo v glavnem širilo po podonavski in sredozemski poti. Na svoji poti se je »srečevalo« s kraškim svetom Balkana, gorskim svetom Alp in prispelo v nižavje srednje Evrope. Med kmetijsko kolonizacijo Evrope se je genetska pestrost domačih živali zmanjševala s povečevanjem razdalje od centra udomačitve. Evropsko govedo se je prilagodilo lokalnim razmeram in rejci so odbirali živali z največjo prirejo mleka in/ali mesa ter z najboljšimi delovnimi sposobnostmi. Pred približno 200 leti so z bolj sistematično selekcijo nastale izenačene populacije in genetsko izolirane pasme s standardiziranimi lastnostmi zunanjosti in prireje (Felius, 1995; Cymbron in sod., 2005; Medugorac in sod., 2009).

Cikasto govedo je bilo, podobno kot druge avtohtone pasme in lokalne populacije goveda, pod vplivom oplemenjevanja in križanja z drugimi pasmami govedi z večjim telesnim okvirom in z večjo prirejo mleka in/ali mesa. V preteklosti je bilo oplemenjeno s pincgavskim govedom, prekrižano z lisastim govedom in zamenjano z rjavim govedom. Poleg tega je preko pincgavskega goveda dobilo še gene rdečega holštajnskega goveda, saj je bilo pincgavsko govedo pod vplivom holsteinizacije (Felius, 1995) v sedemdesetih letih prejšnjega stoletja. Za 59 krav, ki so se ohranile do leta 1992 in so bile vpisane v registru v CPZ Govedo, je bilo znano poreklo in z njim tudi delež drugih pasem (Jeretina, 2004). Za 300 krav, ki so jih našli na odročnih hribovskih in gorskih kmetijah, ni bilo znanih podatkov o poreklu.

Vse živali, tiste z znanim poreklom in tiste, ki so po lastnostih zunanjosti spominjale na cikasto govedo, so bile leta 2002 vpisane v register in kasneje v rodovniško knjigo za cikasto govedo. Na podlagi ocenjevanja lastnosti zunanjosti se je ugotovila velika raznolikost med živalmi znotraj populacije, tako glede višine vihra kot tudi drugih lastnosti zunanjosti. Na podlagi tega so leta 2006 (Žan in sod., 2005) razvili prilagojen sistem za ocenjevanje zunanjosti (Priloga A, Priloga B), da bi lažje ocenili pasemske značilnosti oziroma ugotovili, katere živali so bolj podobne prvotnemu cikastemu govedu, preden je bilo le-to izpostavljeno prilivu genov drugih pasem z oplemenjevanje in križanjem. Na podlagi lastnosti zunanjosti so vse plemenske živali v populaciji razvrstili v cikasti, delni cikasti in pincgavski tip. Velika raznolikost je bila potrjena tudi na podlagi analize variance za lastnosti zunanjosti (Simčič in sod., 2015a). Poleg tega, je bilo ugotovljeno, da na lastnosti zunanjosti v večji ali manjši meri vplivajo tudi dejavniki okolja, kot so leto ocenjevanja, starost ob ocenjevanju in čas po telitvi. Na podlagi tega smo ugotovili, da prihaja do napak pri razvrstitvi živali v tip, ker se pri razvrstitvi ne upošteva vplivov okolja. Poleg tega je razvrstitev živali v ustrezen tip tudi podlaga za odbiro plemenskih bikov in bikovskih mater. Teoretično bi lahko odbrane živali samo na podlagi lastnosti zunanjosti, po genotipu ne pripadale cikastemu govedu.

O podobni problematiki pri pomurskem govedu v Avstriji so poročali že Medugorac in sod. (2009). Pomursko govedo so po drugi svetovni vojni oplemenjevali z rumenim frankovskim govedom in/ali ga zamenjevali z lisastim. V osemdesetih letih prejšnjega stoletja so pričeli z iskanjem tipičnih predstavnikov pasme, da bi ohranili originalno pomursko govedo. Ker so imeli tipični predstavniki pasme enega ali več prednikov v poreklu, ki so pripadali rumenemu govedu, jih niso vključili v program ohranjanja. V program so tako vključili živali pomurskega goveda brez znanega porekla. Ker sta si pomursko in rumeno frankovsko govedo zelo podobna, je pasmi samo po zunanjosti skoraj nemogoče ločiti. Pred nedavnim pa so s filogenetskimi študijami ugotovili, da je ohranjeno pomursko govedo podpopulacija rumenega goveda, ker je z njim tako zelo prekrižano. S tem so pokazali, da ohranjanje in selekcija živali brez znanega porekla in odbira samo na osnovi lastnosti zunanjosti lahko vodi v izgubo genetske identitete določene pasme oziroma do premika populacije k drugi pasmi.

Po barvnemu vzorcu sta si zelo podobna tudi cikasto in pincgavsko govedo in ne moremo z gotovostjo trditi, kateri pasmi pripada posamezna žival oziroma kolikšen delež pincgavskega genotipa je pri posamezni živali v populaciji cikastega goveda. Kljub vpisanim živalim v rodovniški knjigi in uspešnemu povečevanju števila živali, je bila popolnoma nepoznana genetska struktura populacije in sorodnost z drugimi pasmami. Teoretično bi se lahko po genotipu ohranilo cikasto, belansko ali pincgavsko govedo in križanci z lisastim ter rjavim govedom. Poleg tega, bi bila lahko v posamezni živali prisotna še katera druga pasma, saj je bilo znano (Jeretina, 2004), da za osemenjevanje krav cikastega goveda ni bilo na razpolago licenciranih cikastih bikov od leta 1976 dalje. Na voljo je bilo le seme bikov križancev med cikastim in pincgavskim govedom ter seme bikov pincgavskega goveda.

Na podlagi omenjenih dejstev in dvomov, katero govedo se je ohranilo, smo pričeli z zbiranjem vzorcev biološkega materiala iz katerega smo izolirali DNK in določili genotip za izbrano število genetskih označevalcev. Takrat je večina pasem govedi iz sosednjih držav že imela določene genotipe za mikrosatelitne označevalce in raziskovalci, ki so se s tem ukvarjali, so bili povezani v Konzorcij za genetsko raznolikost govedi v Evropi (European Cattle Genetic Diversity Consortium; Felius in sod., 2011) . V konzorcij smo se povezali tudi mi in v skupno zbirko podatkov prispevali 150 genotipov cikastega goveda na podlagi 17 mikrosatelitnih označevalcev. V zameno smo dobili v souporabo genotipe za 42 pasem, ki so geografsko blizu cikastemu govedu ali pa je obstajala možnost, da bi bile načrtno ali nenačrtno prisotne v populaciji cikastega goveda.

Na podlagi mikrosatelitnih genotipov za 150 živali cikastega goveda v primerjavi z genotipi drugih pasem in s pomočjo različnih statističnih programov smo naredili molekularno genetsko karakterizacijo cikastega goveda, ki je zajemala oceno populacijsko genetskih parametrov, izračun genetskih razdalj in sorodnosti med pasmami. Določili smo tudi delež genov drugih pasem v populaciji cikastega goveda (Simčič in sod., 2013a). Ugotovili smo, da je cikasto govedo kljub zmanjšanju velikosti populacije in skorajšnjemu izumrtju v letu 1991, ohranilo relativno visoko stopnjo genetske pestrosti znotraj pasme, ki je večja kot pri alpskih in manjša kot pri balkanskih pasmah. To potrjuje geografsko lego Slovenije in dejstvo, da se genetska raznolikost zmanjšuje z oddaljenostjo od centra udomačitve proti severu ter da cikasto govedo ni bilo podvrženo intenzivni selekciji. Z genetsko analizo v programu Structure smo cikasto govedo ločili od drugih pasem na podlagi edinstvene frekvence alel, ki jo opredeljujejo kot samostojno pasmo. Ne glede na primesi drugih pasem, se je izvorno cikasto govedo ohranilo in lahko smo potrdili, da imamo avtentično avtohtono pasmo govedi, ki predstavlja edinstven genetski vir.

Zaradi oplemenjevanja in križanja populacije cikastega goveda v preteklosti, smo odkrili tudi živali z večjim ali manjšim deležem pincgavskega, lisastega, rdečega holštajnskega in drugega goveda. Večina živali z večjim deležem pincgavskega goveda je bila tudi na podlagi ocenjevanja zunanjosti razvrščena v pincgavski tip. Vendar pa smo odkrili tudi nekaj napačno razvrščenih živali. V cikasti tip so bile npr. razvrščene živali z majhno višino vihra, ki je bila posledica slabega krmljenja, čeprav so imele živali večji delež genov pincgavskega goveda. Živali, ki so imele večji delež genov cikastega goveda so bile razvrščene tako v cikasti, delni cikasti in tudi v pincgavski tip (Simčič in sod., 2013a). S tem smo potrdili domnevo, da živali med seboj ni mogoče ločiti samo na podlagi lastnosti zunanjosti.

Na podlagi vključitve v Konzorcij za genetsko raznolikost govedi v Evropi smo genotipe 66 živali cikastega goveda brez primesi drugih pasem vključili še v večjo študijo, ki je vključevala 167 pasem iz 21 držav (Felius in sod., 2011; Simčič in sod., 2012). Na podlagi genetske raznolikosti med pasmami, zgodovinskega nastanka in geografske lege, kjer je pasma razširjena, smo pripravili nov sistem klasifikacije pasem govedi, ki so razširjene v evropskem prostoru. Pravilna klasifikacija pasem prispeva k poznavanju zgodovine pasem, kar je pomembno za učinkovito ohranjanje genetske raznolikosti. Veliko starejših načinov klasifikacije pasem govedi na podlagi oblike lobanje in rogov ter barve plašča je bilo že pred razvojem molekularne genetike ovrženih. Prav tako je bila ovržena tudi difiletska teorija nastanka evropskega goveda (Felius in sod., 2011), čeprav jo najdemo še marsikje prepisano iz starejše literature (Cizej, 1967) in zapisano kot veljavno, tudi v novejši literaturi (Mitič in sod., 1987; Žan Lotrič, 2012) in v Rejskem programu za cikasto govedo (Žan Lotrič in sod., 2010).

Wilckens (1876) je razvil klasifikacijo goveda na podlagi meritev lobanje, ki je veljala le za pasme, katere je lahko ločil med seboj. Opisal je štiri glavne tipe govedi. *Bos taurus* *primigenius* ali primigeno govedo podobno divjemu turu, kamor je razvrstil podolsko sivo stepsko, nižinsko mlečno in galloway govedo. V *Bos taurus brachyceros* (kratkorožno govedo) imenovano tudi *Bos taurus longifrons* (govedo z dolgim čelom) je razvrstil sivo in rjavo hribovsko govedo. V *Bos taurus frontosus* (govedo s široko glavo) je razvrstil lisasto govedo. V *Bos taurus brachycephalus* (govedo s kratko glavo) je razvrstil herens in tuxer govedo. Pincgavsko in marijadvorsko govedo je pustil kot nerazvrščeno, ker je predvideval, da sta vmesni križani tip med navedenimi tipi.

Adametz (1898) je na podlagi klasifikacije Wilckens-a (1876) in razlik v merah lobanje razvil difiletsko teorijo, s katero je trdil, da je govedo s kratkimi rogovi imenovano *Bos brachyceros* (*Bos longifrons*) nastalo iz avtentičnega evropskega divjega goveda kot neodvisna samostojna udomačitev od *Bos primigenius-a*. Ta difiletska teorija je veljala le v »nemško govorečih šolah« in je ostali niso priznavali. Britanski znanstveniki so pasme goveda ločevali po barvi dlake in barvnemu vzorcu in ignorirali teorijo »nemško govoreče šole«. Leithner (1926), cit. po Felius in sod. (2011), je pojasnil, da ima tudi *Bos brachyceros* izvor v *Bos primigenius-u.* Čeprav teorija »nemške šole« za ločevanje pasem na osnovi lobanje ni bila nikoli povsod sprejeta, se je obdržala do sredine dvajsetega stoletja. Izraz »*primigenius«* se je uporabljal za vse pasme z dolgimi rogovi in izraz »*brachyceros«* za vse pasme s kratkimi rogovi. Ideja o neodvisni domestikaciji »*brachyceros-a«* je bila v knjigah še velikokrat napisana (Cizej, 1967; Mitič in sod., 1987), čeprav že dolgo ni več držala.

Hiter razvoj DNK tehnologij je vplival tudi na proučevanje pasem govedi. Eno pomembnejših odkritij na podlagi DNK je bila potrjena ločena domestikacija evropskega goveda (*Bos taurus,* govedo brez grbe) v jugozahodni Aziji na območju Plodnega polmeseca (Fertile Crescent) od indijskega goveda (*Bos indicus*, govedo z grbo, zebu) v dolini Indus. Drugi ločeni izvori goveda niso bili potrjeni. Na podlagi večjega števila študij je obveljala monofiletska teorija. Sedaj je potrjeno, da ima vse evropsko govedo izvor v jugozahodni Aziji (Fertile Crescent) in da se je govedo s kratko glavo razvilo po domestikaciji (Felius in sod., 2011).

Povezani raziskovalci in združeni podatki o genotipih živali na osnovi mikrosatelitnih označevalcev so bili pogoj za izračun genetskih razdalj med pasmami in za analizo razvrščanja pasem po skupinah na osnovi frekvence alel. Na osnovi molekularno genetskih analiz in geografske bližine so sedaj evropsko-azijske pasme goveda razvrščene v pet glavnih skupin, in sicer: »1. Severno-evropsko govedo«, »2. Centralno-evropsko govedo«, »3. Iberijsko govedo«, »4. Podolsko govedo« in »5. Jugovzhodno evropsko/Jugozahodno azijsko govedo«. Znotraj teh skupin so oblikovane podskupine na različnih nivojih. Cikasto govedo je, na podlagi izračunanih genetskih razdalj in analize razvrščanja v skupine na podlagi rezultatov iz programa Structure, razvrščeno v drugo skupino »Centralno-evropsko govedo« in v peto podskupino »Centralno-vzhodne pasme« (Felius in sod., 2011; Simčič in sod., 2012). Poleg cikastega goveda sta v skupini »Centralno-vzhodne pasme« še pincgavsko in pustariško govedo. Pustariško govedo (pustertaler) je bilo v preteklosti razširjeno na Južnem Tirolskem v Italiji in na Tirolskem v Avstriji. Krave so slovele po izjemni mlečnosti in so bile zelo cenjene pri rejcih v okolici Dunaja, ki so z mlekom oskrbovali mesto. Dunajski rejci so krave in telice kupovali na Tirolskem in jih drago plačevali, s tem pa posredno povzročili, da je danes pustariško govedo ogrožena pasma (Felius, 1999; Sambraus, 1999). Cikastemu govedu smo tako zagotovili večjo prepoznavnost tudi izven meja Slovenije, v evropskem prostoru. Kot avtentična avtohtona pasma bo na podlagi genetske karakterizacije prvič v zgodovini vpisana in predstavljena v novi enciklopediji pasem, ki jo pripravljajo na Univerzi v Lincolnu v Veliki Britaniji.

Genetsko karakterizacijo na osnovi mikrosatelitnih označevalcev smo ponovili z označevalci SNP (Single Nucleotide Polymorphism) večje gostote (Simčič in sod., 2015b). Prav tako smo ocenili parametre genetske raznolikosti in delež primesi drugih pasem ter poskušali pojasniti zgodovino pasme. Zaradi cenovno dražje tehnologije smo vključili samo 76 živali cikastega goveda poleg 531 živali iz 14 referenčnih evropskih populacij/pasem. Za označevalce SNP na BovineSNP50 čipu je bilo ugotovljeno, da raznolikost ocenjujejo pristrano, ker je bil čip izdelan na osnovi vzorca manjšega števila živali iz dobro znanih in razširjenih pasem. Da bi se izognili pristranosti, smo štiri zaporedne označevalce SNP spojili v haplotip. Uporabili smo znane podatke iz porekla, ocene zunanjosti in haplotipe, da bi izboljšali način identifikacije čistopasemskih živali cikastega goveda. S filogenetsko analizo na podlagi označevalcev SNP smo potrdili avtentično genetsko identiteto cikastega goveda. Med cikastim in pincgavskim govedom smo zaznali dolgo in široko povezavo na podlagi izračuna genetskih razdalj. Tudi analiza razvrščanja v skupine (Admixture) in dvo-dimenzionalna razvrstitev sta pokazali, da je cikasto govedo avtentična pasma, čeprav po barvi plašča spominja na pincgavsko govedo. Priporočili smo, da bi lahko s tako analizo z večjim številom genetskih označevalcev dokaj zanesljivo odbirali plemenske bike in bikovske matere. Ugotovili smo tudi, da imajo populacije, ki niso bile pod pritiskom selekcije večjo haplotipsko raznolikost. V takih populacijah ni priporočljivo samo iskanje originalnega genotipa, ampak predvsem odstranjevanje primesi tujih pasem iz takih populacij, saj s tem zmanjšujemo erozijo genske pestrosti. Uspešnost iskanja čistopasemskih živali bi lahko še povečali s kombinirano uporabo ocen lastnosti zunanjosti, znanih podatkov iz porekla in haplotipov na osnovi večjega števila genetskih označevalcev za proučevano pasmo. Poleg tega je potrebno v tako analizo vključiti čim večje število referenčnih pasem, ki so bile kakorkoli povezane s proučevano pasmo. Referenčne pasme so pasme, ki so razširjene v geografski bližini proučevane pasme. Prav tako so to vse pasme, ki so jih v preteklosti uporabljali za oplemenjevanje, križanje ali pretapljanje proučevane pasme. Referenčne pasme so lahko tudi pasme, ki so proučevani pasmi podobne v morfoloških lastnostih zunanjosti in/ali po barvi plašča.

Selekcija cikastega goveda bi morala biti usmerjena predvsem v zmanjševanje primesi pincgavske pasme in v popolno izključevanje primesi drugih pasem na podlagi genotipizacije z večjim številom genetskih označevalcev. Poleg tega je potrebno upoštevati optimalne vrednosti za ocene lastnosti zunanjosti, ki so zapisane v rejskih ciljih. Ocenjeni dednostni deleži za lastnosti zunanjosti prvesnic cikastega goveda so primerljivi z ocenjenimi dednostnimi deleži pri drugih pasmah in omogočajo uporabo za genetsko vrednotenje cikastega goveda. Ocenjene plemenske vrednosti bi omogočale ustreznejšo razvrstitev vsake živali v posamezen tip, kar bi lahko uporabili za učinkovitejšo selekcijo populacije z vidika ohranjanja avtohtonih lastnosti.

Kot edina avtentična in avtohtona pasma govedi v Sloveniji, spada cika med slovensko naravno in kulturno dediščino. Prilagojena je na ekstenzivne pogoje reje v hribovitem svetu in prispeva k ohranjanju alpske krajine, ki ponuja priložnost in možnost za trajnostno kmetovanje. Vse te ugotovitve opravičujejo finančne podpore za ohranjanje pasme in zahtevajo ustrezno selekcijsko delo, preprečevanje parjenja v sorodstvu in kontrolo porekla.

Kljub finančnim podporam države, je ohranjanje pasme bolj upravičeno in povečevanje števila živali v populaciji hitrejše, če od pasme dobimo proizvod, ki ga lahko tržimo. V preteklosti je bilo cikasto govedo kombinirana pasma, namenjena predvsem za prirejo mleka. Danes za tržno prirejo mleka ni več konkurenčna, ker je bila predolgo brez kontrole prireje mleka in selekcije na mlečnost. Poleg tega se je zelo zmanjšalo število živali v populaciji. Prireja mesa s to pasmo je veljala za slabo alternativo, zaradi slabše klavne kakovosti v primerjavi z drugimi pasmami. Z več zaporednimi poskusi pitanja bikov cikastega goveda na PRC Logatec smo želeli poiskati vzrok za slabšo klavno kakovost, katere pokazatelji so bile lastnosti, ki se beležijo na liniji klanja v klavnicah (Simčič in sod., 2008; Simčič in sod., 2011a).

Za začetek, smo v prvem poskusu v jeseni 2008 leta, na PRC Logatec uhlevili osem odstavljenih cikastih bikcev. Krmili smo jih s srednje intenzivnim (S-INT) krmnim obrokom na osnovi travne in koruzne silaže z dodatkom močnih krmil. Bike smo oddali v zakol ob povprečni starosti 20,0 mesecev in s telesno maso 543,6 kg, saj smo pričakovali veliko zamaščenost klavnih trupov v obliki ledvičnega in medeničnega loja, ki je značilna za mlečne pasme. Za primerjavo smo od rejcev odkupili deset klavnih polovic cikastih bikov, ki so bili oddani v zakol po koncu druge pašne sezone, ob povprečni starosti 23,5 mesecev, neposredno s pašnika. Ugotovili smo, da so bili uhlevljeni spitani cikasti biki 3,5 meseca mlajši in so imeli v povprečju za 59 kg težje klavne polovice (294,8 kg) od cikastih bikov vzrejenih na paši (232,8 kg). Poleg tega sta bili pri spitanih bikih značilno boljša mesnatost (7,1) in zamaščenost (5,2) kot pri bikih s paše (mesnatost = 5,4; zamaščenost = 3,4). Na podlagi večje mase klavnih polovic, boljše mesnatosti in zamaščenosti, so bili spitani biki razvrščeni v boljši plačilni razred, kar je pri takratni ceni klavnih polovic pomenilo v povprečju 388,00 € več za klavni trup spitanega cikastega bika v primerjavi s klavnim trupom cikastega bika s paše. Ugotovili smo, da je tehnologija reje bistveno vplivala na klavno kakovost. Biki s paše so bili oddani v zakol nedopitani, kar sta potrdili značilno slabša ocena za zamaščenost klavnega trupa na liniji klanja (3,4) in značilno manjši delež loja v klavni polovici (5,95 %). Priporočali smo, da bi se po koncu pašne sezone take bike spitalo v hlevu, preden bi jih rejci oddali v zakol, saj bi tako izboljšali klavno kakovost in posledično zaslužek pri prodaji (Simčič in sod., 2010; Simčič in sod., 2011b).

V drugem poskusu, ki se je začel v jeseni 2009 smo na PRC Logatec uhlevili skupino 20 odstavljenih bikcev cikastega goveda in za primerjavo še 20 odstavljenih bikcev lisaste pasme (Žgur in sod., 2014). Želeli smo proučiti tradicionalen način pitanja na osnovi voluminozne krme v primerjavi s pitanjem z večjo vsebnostjo energije v krmnem obroku in vpliv na klavno kakovost ter kakovost mesa tako spitanih bikov. V začetku zaključne faze pitanja smo bike obeh pasem razdelili še na dve podskupini. Biki v EXT skupini so dobivali ekstenziven krmni obrok, ki je bil sestavljen iz travne silaže z dodatkom manjše količine koruzne moke, da bi posnemal način pitanja na majhnih hribovskih kmetijah. Biki v S-INT skupini so dobivali srednje intenziven krmni obrok, kjer smo del travne silaže zamenjali s koruzno silažo in sončničnimi tropinami. Bike smo zaklali, ko so dosegli optimalno stopnjo dopitanosti. Ugotovili smo, da pasma ni značilno vplivala na maso ob zakolu, saj so bili biki cikastega goveda le malo lažji od bikov lisaste pasme. Na maso ob zakolu, dnevni prirast in zauživanje krme je značilno vplivala krma. Biki iz EXT skupine so bili ob zakolu lažji, imeli so slabši dnevni prirast in manjše zauživanje krme od bikov v S-INT skupini. Ugotovili smo, da bi morali imeti vsaj biki lisaste pasme obrok z večjo vsebnostjo energije, da bi lahko v celoti izkoristili njihovo zmogljivost za rast. Klavna kakovost bikov je bila med pasmama podobna, saj vpliv pasme ni bil značilen. Na maso toplih polovic je značilno vplivala le krma, saj so imeli biki iz S-INT skupine v povprečju za 40,2 kg težje polovice, medtem ko na klavnost, mesnatost in zamaščenost, krmni obrok ni značilno vplival (Žgur in sod., 2014).

Ko smo med seboj primerjali samo bike cikastega goveda iz drugega poskusa (Simčič in sod., 2011c) na S-INT in EXT obroku, smo ugotovili, da so bili ob zakolu težji in starejši od cikastih bikov iz prvega poskusa, ki smo jih leto prej spitali z enakim S-INT obrokom. Kljub temu, da so bili cikasti biki iz drugega poskusa za skoraj tri mesece starejši ob zakolu, niso bili prekomerno zamaščeni. Masa polovic cikastih bikov ob zakolu in ostali pokazatelji klavne kakovosti bi morali prepričati rejce, da je smiselno spitati cikaste bike iz lastnih čred, če le imajo možnost zagotoviti krmni obrok z nekoliko večjo energijsko vrednostjo. V nasprotnem primeru pa je priporočljivo z ekstenzivnim obrokom bike pitati dlje časa, saj so tudi pri večji starosti še zadovoljivo priraščali brez povečevanja zamaščenosti.

Glede na dejstvo, da se cikasti biki tudi pri večji starosti niso prekomerno zamastili in da so tudi na revnejšem krmnem obroku dosegli primerno mesnatost klavnega trupa, smo zastavili še tretji poskus, v katerem smo proučevali vpliv vključitve druge pašne sezone v tehnologijo pitanja na klavno kakovost (Simčič in sod., 2014a; Simčič in sod., 2014b).

Uhlevili smo 20 odstavljenih cikastih in 19 odstavljenih lisastih bikcev v jeseni 2010 in jih krmili s S-INT krmnim obrokom. Ob začetku pašne sezone spomladi 2011 smo bike obeh pasem razdelili v dve podskupini. Prva podskupina je ostala na S-INT krmnem obroku, drugo podskupino bikov obeh pasem pa smo dali na celodnevno pašo od začetka do konca pašne sezone. Po končani pašni sezoni smo bike dopitali v hlevu z enakim S-INT obrokom, ki so ga dobivali že pred odhodom na pašo. Ob zakolu so bili biki spitani s S-INT obrokom v hlevu težji od bikov, ki so bili v času pašne sezone na paši. Ugotovili smo, da med pasmama ni bilo značilnih razlik v klavni kakovosti, medtem ko je tehnologija pitanja značilno vplivala na klavno kakovost. Biki, ki so bili na paši in kasneje dopitani, so imeli za 12,2 kg lažje klavne polovice, za 1,6 % slabšo klavnost, za 0,6 ocene slabšo mesnatost in za 0,7 ocene slabšo zamaščenost od bikov na S-INT obroku. Kljub temu, da so bile razlike v klavnih lastnostih med različnima tehnologijama reje značilne, pa niso bile velike. Gledano s stališča stroškov krme, je bila paša zagotovo cenejša od krmljenja S-INT obroka v hlevu, kar upraviči nekoliko slabšo klavno kakovost. Potrdili smo, da je mogoče v času pašne sezone bike cikastega goveda vzrediti tudi na paši in jih kasneje dopitati pred zakolom, saj smo iz prvega poskusa že vedeli, da biki ob koncu paše še niso dovolj dopitani. Poleg tega smo v tretjem poskusu cikaste bike pitali s S-INT obrokom do starosti 23,5 mesecev, ko so dosegli v povprečju 674,4 kg telesne mase ob zakolu s primerno oceno za mesnatost in zamaščenost. To je bila tudi največja povprečna masa ob zakolu cikastih bikov iz vseh treh poskusov, s tem, da so še vedno spadali v kategorijo A (mladi biki do 24 mesecev) (Simčič in sod., 2014a; Simčič in sod., 2014b).

Poleg razlik med cikastim in pincgavskim govedom, ki smo jih prikazali z genetskimi analizami, smo našli razlike tudi v klavnih lastnosti (npr. masi toplih polovic) pri obeh pasmah. Kogel in sod. (1997) so poročali, da so imeli biki pincgavskega goveda, stari 16,7 mesecev ob zakolu, maso klavnih polovic 360,3 kg. Biki cikastega goveda so na S-INT obroku dosegli podobno maso toplih polovic (350,2 ± 26,3 kg) šele štiri mesece starejši, pri starosti 22,7 ± 1,1 meseca.

Ob pregledu podatkov o klavni kakovosti drugih pasem govedi v Evropi smo ugotovili, da so bili biki cikastega goveda ob zakolu starejši in težji od bikov večine drugih avtohtonih in kombiniranih pasem (Albertí in sod., 2008). Klavna kakovost bikov cikastega goveda je bila zelo podobna klavni kakovosti bikov avtohtonih pasem aubrac in salers, ki jih redijo na tradicionalen način (Piedrafita in sod., 2003). V preteklosti so krave obeh pasem uporabljali za delo in za prirejo mleka, danes pa jih redijo kot krave dojilje. Biki pasme aubrac so bili odstavljeni ob koncu pašne sezone in preko zime uhlevljeni. Po koncu druge pašne sezone pri starosti 19 mesecev so jih pričeli intenzivno pitati štiri do šest mesecev s koruzno silažo in senom ter z dodatkom močne krme. Bike pasme salers so pričeli pitati pri starosti devet do deset mesecev s travno in koruzno silažo *po volji* z dodatkom močnih krmil. Biki aubrac pasme so bili zaklani pri starosti 23,7 mesecev in telesni masi 753,3 kg. Ob zakolu je bila masa toplih polovic 451,0 kg, klavnost 59,9 %, ocenjena mesnatost 9,5 in zamaščenost 7,8. Biki salers pasme so bili zaklani pri starosti 19,1 mesecev in telesni masi

714,1 kg. Ob zakolu je bila masa toplih polovic 417,1 kg, klavnost 58,5 %, ocenjena mesnatost 8,3 in zamaščenost 8,8. V klavnih polovicah so imeli biki aubrac pasme 76,1 % mesa, 15,4 % kosti in 7,6 % loja, biki salers pa 73,4 % mesa, 15,2 % kosti in 10,0 % loja. Vse klavne lastnosti so bile zelo podobne klavnim lastnostim cikastih bikov. Podobnost med vsemi tremi pasmami je tudi v spremembi namena reje avtohtonih pasem, ki so bile v preteklosti tradicionalno za delo in za prirejo mleka, sedaj pa so postale primerne za rejo kot krave dojilje za prirejo odstavljenih telet za nadaljnje pitanje.

Poleg klavne kakovosti smo proučili tudi kakovost mesa pri bikih iz prvega in drugega poskusa. V prvem poskusu smo v vzorcih mesa iz dolge hrbtne mišice cikastih bikov, spitanih v hlevu s S-INT krmnim obrokom in na paši, določili kemijsko sestavo in sestavo maščobnih kislin. Pričakovano je bilo v mesu spitanih bikov značilno več intramuskularne maščobe v primerjavi z mesom bikov s paše. Tehnologija reje je značilno vplivala na sestavo maščobnih kislin. Razmerje med n-6/n-3PUFA (večkrat nenasičenih maščobnih kislin) je bilo boljše v mesu cikastih bikov s paše v primerjavi z mesom spitanih bikov v hlevu. V travi je bilo namreč več α-linolenske kisline, ki je prekurzor daljših n-3PUFA, kot sta EPA (eikosapentaenojska kislina) in DHA (doikosaheksaenojska kislina), kar se je pokazalo kot večji delež le-teh kislin v mesu prirejenem na paši. Vendar moramo opozoriti, da je poleg tehnologije reje na maščobnokislinsko sestavo vplivala tudi vsebnost intramuskularne maščobe v mesu. S povečevanjem vsebnosti intramuskularne maščobe so se povečali deleži miristinske, palmitinske, stearinske in oleinske kisline ter zmanjšali deleži linolne, α-linolenske, arahidonske, EPA, DPA (doikosapentaenojska kislina) in DHA kisline (Simčič in sod., 2013b). Zelo majhna vsebnost intramuskularne maščobe v mišici ima za posledico, da je le-ta sestavljena predvsem iz fosfolipidov, ki vsebujejo večji delež PUFA (Raes in sod., 2003). Maščobnokislinska sestava je bila ugodnejša v mesu bikov s paše, vendar je k temu pripomogla tudi zelo majhna vsebnost intramuskularne maščobe v tem mesu. Z vidika vpliva na zdravje ljudi je bila ugodna tudi maščobnokislinska sestava spitanih bikov s S-INT obrokom, saj so le ti prejemali v obroku večji delež travne silaže, ki vsebuje tudi α-linolensko kislino. Krmni obroki za pitance v Sloveniji vsebujejo praviloma večji delež travne silaže zaradi geografskih značilnosti države, ker ima veliko več travniških in pašnih površin v primerjavi z njivami za pridelavo koruze in žit.

Ob zakolu bikov iz drugega poskusa smo zbrali vzorce mesa, da bi še bolj podrobno proučili kakovost mesa med biki cikaste in lisaste pasme spitanih na S-INT in EXT obroku (Simčič in sod., 2015c). Proučevali smo vplive pasme in krmnega obroka na pokazatelje kakovosti mesa. Barva svežega mesa je ena izmed pomembnejših lastnosti pri odločitvah porabnikov o nakupu mesa. Ugotovili smo, da je bilo meso cikastih in lisastih bikov podobno svetlo. Hkrati pa je bilo meso cikastih bikov značilno bolj rdeče in rumeno od mesa lisastih bikov. V polovicah cikastih in lisastih bikov je bil podoben delež mesa in med pasmama ni bilo značilnih razlik. Kljub temu pa je bilo v klavnih polovicah cikastih bikov značilno več loja, manj kit in manj kosti v primerjavi s polovicami lisastih bikov.

Poleg tega je bilo razmerje meso : kosti v klavnih polovicah značilno boljše pri cikastih v primerjavi z lisastimi biki. Meso cikastih bikov je imelo podobne senzorične lastnosti kot meso lisastih bikov. Značilna razlika med pasmama je bila samo v aromi, saj so imeli cikasti biki bolj aromatično meso od mesa lisastih bikov. Čeprav razlika ni bila značilna, smo ugotovili, da je bilo meso cikastih bikov nekoliko mehkejše od mesa lisastih bikov, kar je potrdilo tudi merjenje mehkobe z Warner-Bratzlerjevo (WB) strižno silo, ki je bila večja pri rezu vzorcev lisastih bikov. Med pokazatelje kakovosti mesa štejemo tudi vsebnost intramuskularne maščobe in maščobnokislinsko sestavo. Določili smo nekoliko večjo vsebnost intramuskularne maščobe v mesu cikastih bikov v primerjavi z lisastimi, kar je bilo pričakovano glede na večjo vsebnost loja v polovicah cikastih bikov. Posledično je bilo v mesu cikastih bikov značilno več SFA (nasičenih maščobnih kislin) in manj PUFA (večkrat nenasičenih maščobnih kislin) v primerjavi z lisastimi biki. Vsebnost MUFA (enkrat nenasičenih maščobnih kislin) je bila podobna v mesu obeh pasem. Poleg tega krmni obrok ni vplival na vsebnost SFA, MUFA in PUFA. Razmerje med n-6/n-3 PUFA maščobnimi kislinami je bilo značilno manjše v mesu cikastih bikov v primerjavi z lisastimi biki. Tudi vpliv krme je bil značilen, saj so imeli biki iz S-INT skupine v mesu višje razmerje n-6/n-3PUFA od bikov v EXT skupini. Manjše n-6/n-3PUFA razmerje je bilo zaradi večje vsebnosti n-3PUFA v mesu cikastih in lisastih bikov, kar lahko pojasnimo s travno silažo v obeh krmnih obrokih (S-INT, EXT). Meso bikov obeh pasem prirejeno z dvema različnima krmnima obrokoma je imelo n-6/n-3 PUFA razmerje znotraj priporočene vrednosti 10:1 (Commission of European Communities, 1993).

Na splošno uveljavljeno mnenje, da je cikasto govedo neprimerno za prirejo mesa, je verjetno nastalo na podlagi neprimernih tehnologij reje oz. pitanja bikov te pasme. Pri ustrezni tehnologiji pitanja in ob optimalno doseženi stopnji dopitanosti, lahko ti biki dosežejo dobro klavno kakovost, podobno kot biki drugih kombiniranih pasem in križanci. Velika prednost cikastega goveda, v primerjavi z drugimi pasmami, je manjši delež kosti v klavnih polovicah in sposobnost za pitanje do večje telesne mase in starosti, ne da bi se prekomerno zamastili. Menimo, da smo z vsemi izpeljanimi poskusi pitanja cikastih bikov na PRC Logatec, pomembno doprinesli k boljšemu poznavanju pitovnih in klavnih lastnosti ter lastnosti mesa mladih bikov cikastega goveda. Želimo si, da bi bila pasma tudi z vidika prireje mesa sedaj bolj realno vrednotena.

Cikasto govedo redijo na majhnih, tudi ekoloških kmetijah, v poletnem času na paši brez dodajanja močnih krmil. Pasma je zelo prilagojena na okolje in primerna za sonaravno (ekološko) kmetijstvo, še posebno na marginalnih območjih. To bi lahko bila priložnost za rejce cikastega goveda, za promocijo pasme, njene dobre klavne kakovosti in kakovostnega mesa. Kakovost mesa je namreč primerljiva z mesom bikov lisaste pasme in tudi drugih avtohtonih pasem govedi v Evropi, katerih rejci so že našli tržno nišo za prodajo kakovostnih proizvodov. Kot bližnji primer uspešnega trženja mesa avtohtone pasme lahko vzamemo meso istrskega goveda v Istri na Hrvaškem (Caput in sod., 2009).

3.2 SKLEPI

Na lastnosti zunanjosti vpliva več dejavnikov. V tem delu smo ugotovili značilen vpliv leta ocenjevanja, starosti ob ocenjevanju in števila dni po telitvi, kar lahko posledično povzroči nepravilno razvrstitev živali v ustrezen tip v skladu z rejskim programom. Telesne kondicije se ob ocenjevanju zunanjosti ne zabeleži, zato tega vpliva nismo mogli proučiti. Ocenjeni dednostni deleži za lastnosti zunanjosti prvesnic cikastega goveda so primerljivi z ocenjenimi dednostnimi deleži pri drugih pasmah in omogočajo možnost uporabe za genetsko vrednotenje. Ocenjene plemenske vrednosti omogočajo ustreznejšo razvrstitev živali glede na tip, kar lahko uporabimo za učinkovitejšo selekcijo populacije z vidika ohranjanja avtohtonih lastnosti.

Cikasto govedo je avtentična avtohtona pasma govedi v Sloveniji, kar smo potrdili z genetsko karakterizacijo na osnovi genetskih mikrosatelitnih označevalcev in označevalcev SNP v primerjavi z drugimi referenčnimi pasmami. V skladu z novo klasifikacijo na osnovi genetske raznolikosti, geografske bližine in zgodovine pasem je cikasto govedo razvrščeno v drugo skupino »Centralno-evropsko govedo« in v peto podskupino »Centralno-vzhodne pasme«, kjer sta še pincgavsko in pustariško govedo. Kot avtentična avtohtona pasma bo na podlagi genetske karakterizacije vpisana in predstavljena v novi enciklopediji pasem, ki jo pripravljajo na Univerzi v Lincolnu v Veliki Britaniji.

Mladi biki cikastega goveda so ob ustrezni tehnologiji pitanja povsem primerni za prirejo mesa. Dosegajo dobro klavno kakovost in kakovost mesa, ki je primerljiva z drugimi kombiniranimi in avtohtonimi pasmami govedi v Evropi. Velika prednost cikastega goveda je manjši delež kosti v klavnih polovicah in sposobnost za pitanje do večje telesne mase in starosti ob zakolu, ne da bi se pri tem prekomerno zamastili.

4 POVZETEK (SUMMARY)

4.1 POVZETEK

Glavni namen te disertacije je bil proučevanje cikastega goveda, ki je edina avtohtona pasma govedi v Sloveniji. V preteklosti je bila ta pasma razširjena predvsem v Alpah in predalpskem svetu sedanje Slovenije. Danes je cikasto govedo razširjeno skoraj po vsej Sloveniji. Po podatkih Službe za identifikacijo in registracijo (SIR) je bilo v juniju 2014 v Sloveniji 3.351 živali cikastega goveda. V centralni podatkovni zbirki (CPZ) Govedo na Kmetijskem inštitutu Slovenije je bilo v decembru 2014 v rodovniški knjigi za cikasto govedo vpisanih 2.021 čistopasemskih plemenic, od katerih jih je bilo 379 v glavnem razdelku rodovniške knjige.

Razvoj cikastega goveda je bil na podlagi pisnih zgodovinskih virov podrobno proučen v doktorski disertaciji (Žan Lotrič, 2012). Govedo na Kranjskem je bilo prvič popisano leta 1872 kot govedo brez posebnega imena, rumene, rdeče, rdečerjave in rjavočrne barve (Schollmayr, 1873). V letu 1878 je bilo opisano bohinjsko govedo (Hitz, 1878), rjavordeče barve z lepim telesnim okvirom, tankih kosti in z relativno veliko mlečnostjo. Bohinjsko govedo so kasneje oplemenjevali z biki belanskega goveda (Mölltaler). Na Gorenjskem je Povše (1893) opisal rdeče pisano gorenjsko govedo. Poleg tega je opisal tudi skromno in mlečno bohinjsko govedo, ki ga ni imenoval kot posebno pasmo. V Posočju je Povše (1894) opisal tolminsko in bovško govedo kot lažji tip belanskega goveda z veliko mlečnostjo.

Belansko govedo je imelo relativno majhen telesni okvir, temnejšo rdečo osnovno barvo dlake in zelo dobro mlečnost, a je bilo leta 1925 priključeno k pincgavskemu govedu in je tako izumrlo (Sambraus, 1999). Ko je prvotno enobarvno lokalno govedo, ob koncu 19. stoletja na ozemlju današnje Slovenije, od belanskega goveda prevzelo barvni vzorec, so ga poimenovali cikasto govedo. Po barvnem vzorcu je bilo podobno belanskemu govedu, po telesnih oblikah pa prvotnemu lokalnemu govedu (Ferčej, 1947). Leta 1935 so bila v Službenem listu kraljevske banske uprave dravske banovine kot Banova uredba objavljena »Navodila za presojo barvnih znakov cikastega goveda« (Navodila za presojo…, 1935).

Po letu 1935 so za namen oplemenjevanja cikastega goveda začeli uvažati bike pincgavskega goveda iz Avstrije, katerih je bilo na slovenskem ozemlju največ v času druge svetovne vojne (Žan Lotrič, 2012). Posledično sta se oblikovala dva različna tipa cikastega goveda, večji "ravninski" in manjši "planinski" ali "Bohinjski" tip (Ferčej, 1947). V času po drugi svetovni vojni je bilo v Sloveniji okoli 80.000 glav cikastega goveda (Čepon in sod., 1999). To pasmo so redili zlasti za prirejo mleka in za predelavo le-tega v sir. Na območjih, kjer je prevladovalo cikasto govedo, naj bi bila teleta neprimerna za intenzivno prirejo mesa, zato je bilo leta 1964 sklenjeno, da se cikasto govedo na Gorenjskem pretopi z lisastim govedom. Na Tolminskem so cikasto govedo začeli zamenjevati z rjavim govedom. Manjše število rejcev na odročnih kmetijah je še naprej uporabljalo licencirane bike cikastega goveda za naravni pripust. Takšni pripusti po letu 1976 niso bili več dovoljeni, a so nekateri rejci nadaljevali s prepovedanimi pripusti z nelicenciranimi biki cikastega goveda. Za osemenjevanje je bilo po letu 1976 na voljo seme uvoženih bikov pincgavskega goveda in seme bikov križancev s 25 - 50 % genov cikastega goveda in 50 - 75 % genov pincgavskega ali rdečega holštajnskega goveda (Jeretina, 2004).

Reja cikastega goveda je ostala brez načrtnega selekcijskega dela. Število živali se je zmanjševalo do leta 1992, ko je bilo v registru govedi na Kmetijskem inštitutu Slovenije le še 59 krav cikastega goveda, ki so imele znano poreklo (Jeretina, 2004). V letu 2002 se je pričelo sistematično iskanje živali cikastega goveda za namen ohranjanja. Kmalu je postalo jasno, da so cikasto govedo redili in ohranili rejci na hribovskih kmetijah na Kamniškem in na območju Bohinja, kjer so se uprli prepovedi naravnega pripusta in nadaljevali z uporabo nelicenciranih cikastih bikov. Na novo je bilo registriranih še okoli 300 živali cikastega goveda, ki so bile potencialno brez primesi pincgavskega goveda. Zaradi neznanega porekla in podobnosti v barvnem vzorcu cikastega in pincgavskega goveda je bilo nemogoče izključiti živali s primesmi pincgavskega goveda. Vse živali, ki so bile po zunanjosti podobne cikastemu govedu, so bile vpisane v register in kasneje v rodovniško knjigo kot cikasto govedo. Za cikasto govedo je bil leta 2005 sprejet in potrjen rejski program (Žan in sod., 2005). Leta 2010 se je rejski program nekoliko dopolnil in ponovno sprejel (Žan Lotrič in sod., 2010). Selekcija cikastega goveda sedaj temelji na ocenjevanju lastnosti zunanjosti pri potencialnih plemenskih bikih ter pri vseh prvesnicah. Leta 2006 (Žan Lotrič in sod., 2010) se je ponovno ocenila zunanjost vsem plemenskim živalim z vključitvijo tako imenovanih »avtohtonih lastnosti«. Pregled je pokazal velike razlike v lastnostih zunanjosti med živalmi v populaciji cikastega goveda, zato so bile vse živali razvrščene v tri tipe in sicer: cikasti, delni cikasti in pincgavski tip. Razvrščanje živali v tip na podlagi ocene za sestavljeno lastnost avtohtonost, se izvede istočasno ob ocenjevanju, kar onemogoča, da bi upoštevali morebitne vplive okolja.

V disertaciji smo uporabili večje število različnih zbirk podatkov in z njimi preverili več hipotez. V prvi hipotezi smo predpostavili, da na lastnosti zunanjosti in posledično na razvrstitev živali v ustrezen tip vplivajo poleg genetskih tudi vplivi okolja. Cilj raziskave je bila analiza lastnosti zunanjosti pri 330 plemenskih bikih in 1.086 prvesnicah cikastega goveda. Proučili smo štiri merjene lastnosti pri prvesnicah in sedem pri plemenskih bikih. Posamezne ocenjevane lastnosti na linearni lestvici od 1 do 9 so bile razdeljene v tri sklope in sicer, avtohtonost, telesne oblike in vime pri prvesnicah. Sestavljene ocenjevane lastnosti so bile tri pri plemenskih bikih in štiri pri prvesnicah. S proceduro GLM v statističnem paketu SAS smo ocenili vplive na posamezno lastnost. Sistematski del statističnega modela za plemenske bike je vključeval vpliv leta ocenjevanja in starost živali ob ocenjevanju kot linearno regresijo. Sistematski del statističnega modela za prvesnice pa je poleg teh, vključeval še čas po telitvi kot linearno regresijo. Pri prvesnicah smo z modelom živali ocenili tudi parametre disperzije za vse lastnosti zunanjosti. Uporabili smo metodo REML v paketu VCE-6. Poleg sistematskih vplivov je model živali vključeval še naključni vpliv črede in aditivni genetski vpliv živali. Vse razpoložljive informacije o prednikih živali z meritvami (1.747 živali) smo uporabili za izgradnjo matrike sorodstva. V povprečju so bili 14,6 mesecev stari plemenski biki v vihru visoki 117,1 cm, prvesnice pa 126,5 cm pri starosti 33,9 mesecev. Ker se živali v populaciji cikastega goveda glede na lastnosti zunanjosti med seboj zelo razlikujejo, so vse plemenske živali razdeljene še na tip. Na podlagi višine vihra in ocen zunanjosti iz sklopa avtohtonost so bili plemenski biki in prvesnice razdeljeni na cikasti tip (186 ♂, 213 ♀), delni cikasti tip (142 ♂, 681 ♀) in pincgavski tip (2 ♂, 192 ♀). Plemenski biki v cikastem tipu so bili v vihru visoki 115,8 cm pri 14,3 mesecih, prvesnice 121,8 cm pri 32,6 mesecih in so imeli povprečno oceno za sestavljeno lastnost avtohtonost 7,22 (♂) in 7,19 (♀). Ocenjeni dednostni deleži za merjene lastnosti so bili od 0,48 do 0,79, za posamezne ocenjevane lastnosti za avtohtonost od 0,37 do 0,87, za posamezne lastnosti za telesne oblike od 0,17 do 0,70 in za posamezne lastnosti za vime od 0,26 do 0,51. Ocenjeni dednostni deleži za sestavljene lastnosti avtohtonost, omišičenost, telesne oblike in vime so bili 0,62, 0,29, 0,20 in 0,30. Delež pojasnjene variance z vplivom črede za merjene lastnosti je bil od 0,08 do 0,25, za posamezne lastnosti za avtohtonost od 0,01 do 0,08, za posamezne lastnosti za telesne oblike od 0,01 do 0,20 in za posamezne lastnosti za vime od 0,06 do 0,15. Deleži pojasnjene variance z vplivom črede za sestavljene lastnosti avtohtonost, omišičenost, telesne oblike in vime so bili 0,10, 0,27, 0,09 in 0,13. Ocene genetskih korelacij med merjenimi lastnostmi so bile od 0,87 do 0,99, med posameznimi lastnostmi za avtohtonost od -0,10 do 0,96, med posameznimi lastnostmi za telesne oblike od -0,55 do 0,90 in med posameznimi lastnostmi za vime od -0,79 do 0,96. Ocenjene korelacije so bile visoke med lastnostmi, ki opisujejo podobne morfološke značilnosti, npr. lastnosti telesnega okvira, vimena ter beli pasovi na prednjih in zadnjih nogah. Ocenjeni dednostni deleži za lastnosti zunanjosti prvesnic cikastega goveda so primerljivi z drugimi pasmami in jih lahko uporabimo za genetsko vrednotenje lastnosti zunanjosti. Ocenjene plemenske vrednosti omogočajo ustreznejšo razvrstitev živali v posamezne tipe, kar lahko uporabimo za učinkovitejšo selekcijo populacije, še posebno z vidika ohranjanja avtohtonih lastnosti.

Glede na vsa dejstva iz zgodovinskih zapisov in zaradi velikih razlik v zunanjosti med posameznimi živalmi v populaciji cikastega goveda nismo mogli trditi, da je ohranjeno govedo res prvotno cikasto govedo. V drugi hipotezi smo predpostavili, da je ohranjeno cikasto govedo avtentična avtohtona pasma, ki je genetsko različna od pincgavskega goveda in od drugih pasem v Alpah. Naredili smo genetsko karakterizacijo cikastega goveda, da bi ocenili status avtohtone pasme. Primerjali smo genotipe za 14 mikrosatelitnih označevalcev pri 150 živali cikastega goveda z genotipi 16 pasem govedi iz srednje Evrope. Pokazali smo, da je cikasto govedo genetsko enako raznoliko kot druge alpske pasme, bolj raznoliko od avstrijskega lisastega goveda, vendar manj od balkanske buše. Analiza s programom Structure je pokazala primesi pincgavskega goveda pri večjem številu živali, vendar je zaznala tudi edinstveno genetsko identiteto cikastega goveda. Ta analiza omogoča izbor genetsko najbolj čistih živali cikastega goveda, kar je bilo ocenjeno z naborom mikrosatelitnih označevalcev. Cikasto govedo je potrebno obravnavati kot avtentično pasmo in je dragocen genetski vir.

V zadnjem času se čedalje bolj uveljavljajo genetski označevalci SNP. Genotipizacija z velikim številom označevalcev SNP (BovineSNP50 čip) je postala finančno ugodnejša in hkrati nudi večje število informacij o genomu. Cilj raziskave je bil pridobiti nepristrane ocene parametrov raznolikosti, določiti deleže primesi drugih pasem v genomu cikastega goveda in pojasniti zgodovino populacije. Genetske analize so bile narejene na osnovi večjega števila polimorfizmov na posameznem nukleotidu (SNP) pri 76 živalih cikastega goveda in pri 531 živalih iz 14 referenčnih populacij. Za pridobitev nepristranih ocen smo uporabili kratke haplotipe iz štirih označevalcev SNP namesto posameznega SNP, da bi se izognili pristranosti BovineSNP50 čipa. Haplotipi po celem genomu v kombinaciji z nepopolnim poreklom in ocenami za lastnosti zunanjosti so pokazali potencial za izboljšanje identifikacije čistopasemskih živali z majhnim deležem primesi. Filogenetske analize so pokazale edinstveno genetsko identiteto živali cikastega goveda. Matrika genetskih razdalj v obliki mreže je pokazala dolgo in široko filogenetsko povezavo med cikastim in pincgavskim govedom. Nenadzorovano oblikovanje skupin narejeno z »Admixture« analizo in dvodimenzionalen prikaz genetskih razdalj med posameznimi živalmi sta tudi pokazala, da je cika edinstvena pasma, čeprav je po videzu podobna pincgavcu. Živali, ki so bile identificirane kot najbolj čistopasemske, se lahko uporabljajo kot jedro za reševanje avtohtonega genetskega ozadja v sedanji populaciji. Rezultati so pokazali veliko haplotipsko raznolikost lokalno dobro prilagojenih populacij, ki jih rejci niso nikoli intenzivno odbirali in selekcionirali v določeno pasmo. Vse to predlaga način ohranjanja in reševanja, ki se ne opira izključno na iskanje prvotnega avtohtonega genetskega ozadja, ampak predlaga predvsem identifikacijo in odstranitev tujih primešanih haplotipov, kar bi bolj učinkovito zmanjšalo erozijo genetske pestrosti. Uspešna uvedba takšnega načina bi morala temeljiti na združevanju podatkov iz ocenjevanja lastnosti zunanjosti, podatkov v poreklu in haplotipov iz celega genoma za proučevano pasmo in za spekter referenčnih pasem, ki so morebiti imeli neposreden ali posreden prispevek h genetskemu oblikovanju proučevane pasme.

V preteklosti je bilo cikasto govedo v glavnem namenjeno za prirejo mleka. Danes je mlečnost krav majhna v primerjavi z drugimi pasmami, ki so usmerjene v tržno prirejo mleka. V rejskem programu je sicer zapisano, da je cikasto govedo kombinirana pasma s poudarkom na prireji mleka (Žan Lotrič in sod., 2010). Sedaj večino krav redijo kot krave dojilje, kjer je glavni proizvod odstavljeno tele ob koncu laktacije. Povše (1894) je zapisal, da je bilo meso tolminskega goveda zelo cenjeno pri mesarjih v Trstu in Gorici. V tretji hipotezi smo predpostavili, da so biki cikastega goveda ob ustrezni tehnologiji pitanja primerni za prirejo mesa in imajo primerljivo klavno kakovost in kakovost mesa z ostalimi kombiniranimi pasmami govedi v Sloveniji.

Populacija cikastega goveda se je zadnja leta povečevala, zato je bilo na voljo vse več odstavljenih bikcev ob koncu pašne sezone primernih za nadaljnje pitanje. To je vodilo k odločitvi, da smo od rejcev začeli odkupovati odstavljene bikce vsako leto po koncu pašne sezone, več let zapored. Odstavljene bikce približno enake telesne mase in starosti smo vsako leto v jeseni uhlevili na PRC Logatec in izvedli več poskusov pitanja.

Cilj raziskave je bil ugotoviti kako tradicionalen način dopitanja s krmnim obrokom na osnovi voluminozne krme v primerjavi s krmnim obrokom z večjo energijsko vrednostjo vpliva na rast, klavne lastnosti in obnašanje ob krmljenju pri bikih cikastega in lisastega goveda (20 bikov na pasmo). Poskusna krmna obroka sta bila: extenzivni (EXT) na osnovi travne silaže in srednje intenzivni (S-INT), v katerem je bil del travne silaže nadomeščen s koruzno silažo in sončnično moko. Oba krmna obroka sta bila krmljena *po želji* desetim bikom cikaste in desetim bikom lisaste pasme, ki so bili uhlevljeni v skupinskih boksih po pet živali skupaj. Zmogljivost za rast je bila podobna pri bikih obeh pasem, vendar so biki cikastega goveda dosegli komercialno stopnjo dopitanosti en mesec pred biki lisaste pasme (139 *vs.* 167 dni, $p = 0{,}016$). Biki krmljeni s S-INT obrokom so bili težji ob zakolu (645,3 *vs.* 590,1 kg; $p = 0{,}05$), imeli so večji povprečni dnevni prirast (1,05 *vs.* 0,83 kg, $p = 0{,}026$) in zauživanje krme (11,7 *vs.* 10,6 kg suhe snovi (SS)/dan, $p < 0{,}001$) kot biki krmljeni z EXT obrokom. Ne glede na pasmo in krmni obrok so biki zaužili 77 - 80 % dnevne SS v prvih osmih urah po razdelitvi krme. Biki krmljeni z EXT obrokom so dlje časa stali (406,4 *vs.* 355,8 min, $p < 0{,}001$) in uživali krmo (217,2 *vs.* 155,3 min, $p <0{,}001$) in krajši čas prežvekovali (77,5 *vs.* 92,9 min; $p < 0{,}001$) kot S-INT krmljeni biki v prvih osmih urah po razdelitvi krme. Biki cikastega goveda so imeli lažji polni vamp in kapico glede na relativno telesno maso ob zakolu (8,7 *vs.* 10,7 %; $p = 0{,}002$) kot biki lisaste pasme. Taki pozitivni rezultati doseženi s cikastim govedom bi morali spodbuditi rejce, da bi vzredili mlade bikce za prirejo mesa, s čimer bi prispevali k ohranitvi tega genskega vira. Poleg tega bi morali povečati tudi delež energije z dodajanjem močnih krmil v krmne obroke na osnovi voluminozne krme.

Klavne lastnosti in lastnosti mesa smo analizirali s statističnim paketom SAS/STAT z uporabo procedure GLM. V model smo vključili pasmo in krmo kot sistematska vpliva. Sestavo maščobnih kislin smo analizirali s proceduro GLM, kjer smo v model vključili pasmo, krmo in interakcijo pasma × krma kot sistematske vplive. Cikasti biki so imeli manjšo maso klavnega trupa (332,64 ± 6,63 kg) in značilno boljšo klavnost (55,79 ± 0,35 %), v primerjavi z biki lisaste pasme (348,72 ± 6,63 kg, 54,42 ± 0,35 %). Cikasti in lisasti biki so imeli podobno svetlo (L*) meso (35,63 ± 0,36; 35,86 ± 0,36), medtem ko so imeli cikasti biki značilno bolj rdeče (a* = 24,98 ± 0,58) in bolj rumeno (b* = 11,56 ± 0,35) meso od lisastih bikov (a* = 21,55 ± 0,58, b* = 9,83 ± 0,35). Z disekcijo desne klavne polovice smo dobili 73,66 ± 0,37 % mesa, 9,51 ± 0,36 % loja, 1,48 ± 0,05 % kit in 15,35 ± 0,21 % kosti pri cikastih bikih, medtem ko so bile polovice lisastih bikov sestavljene iz 73,37 ± 0,37 % mesa, 8,20 ± 0,36 % loja, 1,81 ± 0,05 % kit in 16,63 ± 0,21 % kosti. Warner-Bratzlerjeva strižna sila je bila nekoliko večja pri vzorcih mesa bikov lisaste (49,32 ± 3,92 N) v primerjavi s cikasto pasmo (43,16 ± 3,91 N), vendar razlika ni bila značilna. Vsebnost skupne intramuskularne maščobe je bila značilno večja v mesu cikastih bikov (24,06 ± 1,95 g/kg) v primerjavi z lisastimi biki (13,02 ± 1,95 g/kg), kar bi bilo mogoče pojasniti z manjšo starostjo ob zakolu pri mladih bikih lisaste pasme glede na to, da vpliv krme ni bil značilen. Meso cikastih bikov je vsebovalo značilno več SFA (48,61 ± 0,36 %) in manj PUFA (12,65 ± 1,10 %) v primerjavi z lisastimi biki (45,28 ± 0,36 %, 18,28 ± 1,10 %). Krma ni značilno vplivala na delež SFA, MUFA in PUFA v mesu obeh pasem. Rezultati te raziskave so pokazali, da lahko s cikastimi biki priredimo meso dobre kakovosti. Fizikalne in kemijske lastnosti so primerljive s kakovostjo mesa bikov lisaste in nekaterih drugih pasem govedi v Evropi, katerih rejci so že našli "lokalne tržne niše" za proizvode teh pasem.

V doktorski disertaciji smo potrdili vse tri hipoteze. Potrdili smo, da na ocene zunanjosti vpliva več dejavnikov okolja, kar je lahko posledično povzročilo nepravilno razvrstitev živali v ustrezen tip. Ocenjeni dednostni deleži za lastnosti zunanjosti cikastega goveda so primerljivi z drugimi pasmami in jih lahko uporabimo za genetsko vrednotenje lastnosti zunanjosti cikastega goveda. Ocenjene plemenske vrednosti omogočajo ustreznejšo razvrstitev živali glede na tip, kar lahko uporabimo za učinkovitejšo selekcijo populacije z vidika ohranjanja avtohtonih lastnosti.

Z genetsko karakterizacijo na osnovi genetskih mikrosatelitnih označevalcev in označevalcev SNP smo potrdili, da je cikasto govedo avtentična avtohtona pasma v Sloveniji. V skladu z novo klasifikacijo pasem na osnovi genetske raznolikosti, geografske bližine in zgodovine pasem je sedaj cikasto govedo razvrščeno v drugo skupino »Centralno-evropsko govedo« in v peto podskupino »Centralno-vzhodne pasme«, kamor sta razvrščeni tudi pincgavsko in pustariško govedo. Cika bo kot avtentična avtohtona pasma na podlagi genetske karakterizacije predstavljena v novi enciklopediji pasem, ki jo pripravljajo na Univerzi v Lincolnu v Veliki Britaniji.

Potrdili smo, da so mladi biki cikastega goveda ob ustrezni tehnologiji pitanja povsem primerni za prirejo mesa. Dosegajo dobro klavno kakovost in kakovost mesa, ki je primerljiva z drugimi kombiniranimi in avtohtonimi pasmami govedi v Evropi. Velika prednost cikastega goveda je manjši delež kosti v klavnih polovicah in sposobnost za pitanje do večje telesne mase in starosti, brez prekomerne zamaščenosti klavnega trupa.

4.2 SUMMARY

The main objective of the present dissertation is the survey of Cika cattle which is at present considered as the only Slovenian autochthonous cattle breed. In the past, this breed was spread mainly in the Alps and in the Sub-Alpine parts of present-day Slovenia. Today, it is spread almost all over Slovenia. In June 2014 according to the Office for the

identification and registration (SIR) there were 3351 animals of Cika cattle in Slovenia. In December 2014, the herd book for Cika cattle, managed at the Agricultural Institute of Slovenia, included 2021 registered pure-bred females, where 379 of them were in the main section of the herd book.

Development of Cika cattle was examined in detail on the basis of written historical sources and described in the dissertation of Žan Lotrič (2012). Cattle in Carniola was for the first time surveyed in 1872 and noted as cattle without a specific name of yellow, red, redbrown or brownblack colours (Schollmayr, 1873). Bohinj cattle was described in 1878 (Hitz, 1878) as brownred cattle with a beautiful body frame, thin bones and a relatively high milk yield. Bohinj cattle was later improved with the bulls of Mölltaler cattle. Povše (1893) described the Red Pied Upper Carniola cattle. In addition, he described the poor and dairy Bohinj cattle, which was not named as a specific breed. Povše (1894) described Tolmin and Bovec cattle, found in the river Soča valley, as a lighter type of Mölltaler cattle with a high milk yield.

Mölltaler cattle had a relatively small body frame, dark red basic coat colour and a very high milk yield, but in 1925 it was disseminated to Pinzgauer cattle and thus become extinct (Sambraus, 1999). When the original single coloured local cattle at the end of the 19th century, in the territory of present-day Slovenia, took the coat colour pattern from the Mölltaler cattle, they named it as Cika cattle. The coat colour pattern was similar to the Mölltaler cattle, and the body frame was like the original local cattle (Ferčej, 1947). In the official Journal of the Royal Ban Administration of the Drava province the Ban regulation "Guidelines for the assessment of the coat colour signs of Cika cattle" was published in the year 1935 (Navodila za presojo..., 1935).

After the year 1935 for the purpose of improving Cika cattle, the import of Pinzgauer bulls from Austria has started. Pinzgauer bulls were the most widespread in Slovenia at times after the Second World War (Žan Lotrič, 2012). As a result, two different types of Cika cattle were created, large "lowland" and small "mountain" or "Bohinj" type (Ferčej, 1947). After the Second World War there were around 80,000 heads of Cika cattle in Slovenia (Čepon et al., 1999). This breed was bred especially for milk production. Most of milk yield was processed into cheese. In the areas where Cika cattle dominated, calves were considered as unsuitable for intensive meat production. Consequently, in 1964 it was concluded that Cika cattle needs to be displacing crossed with Simmental in the Upper Carniola region. In the Upper Soča valley Cika was replaced by Brown cattle. A low number of breeders in the marginal farms continued using the licensed Cika bulls for natural service. Despite natural service was banned after the year 1976, some breeders still continued to use unlicensed Cika bulls. After the year 1976, the semen of imported Pinzgauer sires was available for the insemination of Cika cows as well as the semen of crossbred Cika sires with 25-50% of Cika cattle and 50-75% of Pinzgauer or Red Holstein cattle (Jeretina, 2004).

Breeding of Cika cattle has been without a systematic selection work for quite some years. The population size of Cika cattle was decreasing till 1992. Only 59 cows that had known pedigree were recorded in the Register at the Agricultural Institute of Slovenia (Jeretina, 2004). In 2002, a systematic searching of Cika animals for conservation purposes had begun. It soon became clear that Cika cattle was preserved and maintained by the breeders on the mountain farms in Kamnik and Bohinj area. They rebelled the ban of the natural service and continued using unlicensed Cika bulls. For the first time, about 300 Cika animals were registered with potentially no Pinzgauer admixture. Due to the unknown pedigree and similarities in the coat colour pattern of Cika and Pinzgauer cattle, it was impossible to exclude Cika animals with Pinzgauer admixture. All animals which were similar in type traits to Cika cattle were registered in the herd book of Cika breed. Cika cattle breeding program was adopted and confirmed in 2005 (Žan et al., 2005). In 2010, the breeding program was slightly modified and re-adopted (Žan Lotrič et al., 2010). Breeding of Cika cattle is now based on the type traits scoring for young bulls for the artificial insemination and natural service, as well as first-parity cows. In 2006 (Žan Lotrič et al., 2010) the type traits scoring was repeated for all breeding animals with included the so-called "autochthonous characteristics". The review showed significant differences in the type traits among animals of Cika population. All animals were divided into three types like: Cika, Semi-Cika and Pinzgauer type. Classification of each animal in the appropriate type based on the score for the composite autochthonous trait was carried out immediately after the scoring, which made it impossible to consider the potential environmental effects.

In this dissertation, we used a number of different databases and checked several hypotheses. In the first hypothesis, we assumed that the type traits and therefore the classification of animals in the appropriate type are affected by the environmental effects, besides the genetic influences.

The aim of the research was to analyse the measured and scored type traits of 330 sires and 1086 first-parity cows of Cika cattle. We examined four measured traits of first parity cows and seven measured traits of sires. Individual traits scored on a linear scale from 1 to 9 were divided into three groups, autochthonous traits, form and udder. The composite scored traits were three for sires and four for first-parity cows. The GLM procedure in the statistical package SAS was used to determine environmental effects on a particular trait. Fixed part of the statistical model used for sires included fixed effects of scoring year and age at scoring as linear regression. Fixed part of the statistical model used for cows included fixed effects of scoring year, as well as age at scoring and time after calving as linear regressions. Based on the animal model for first-parity cows the dispersion parameters were assess for all type traits. We used the REML method in the VCE-6 package. In addition to included fixed effects, animal model included the random herd effect and additive genetic effect. All available ancestors' information of animals with records (1,747 animals) were used for the relationship matrix construction. On average, 14.6 months old sires had 117.1 cm wither height, while first-parity cows at the age of 33.9

months had 126.5 cm in wither. Since animals in Cika population vary widely in type traits, they were subdivided into different types. Sires and cows were classified on the base of wither height and score for composite autochthonous trait into Cika type (186 ♂, 213♀), semi Cika type (142 ♂, 681♀) and Pinzgauer type (2 ♂, 192♀). Sires in Cika type were in withers 115.8 cm at 14.3 months, first-parity cows were 121.8 cm at 32.6 months and had composite autochthonous trait 7.22 (♂) and 7.19 (♀), respectively. Estimated heritabilities for measured traits were from 0.48 to 0.79, for individual autochthonous traits from 0.37 to 0.87, for individual form traits from 0.17 to 0.70, and for individual udder traits from 0.26 to 0.51. Estimated heritabilities for the composite traits of autochthonous, muscularity, form and udder were 0.62, 0.29, 0.20 and 0.30. Estimated herd variance ratios for measured traits were from 0.08 to 0.25, for individual autochthonous traits from 0.01 to 0.08, for individual form traits from 0.01 to 0.20 and for individual udder traits from 0.06 to 0.15. Estimated herd variance ratios for composite traits of autochthonous, muscularity, form and udder were 0.10, 0.27, 0.09 and 0.13. Estimated genetic correlations among the measured traits were from 0.87 to 0.99, among individual autochthonous traits (-0.10 to 0.96), among individual form traits (-0.55 to 0.90) and among individual udder traits (-0.79 to 0.96). Estimated correlations were high among traits that describe similar morphological characteristics, for example body frame, udder, white bands on the fore and hind legs. Estimated heritabilities for type traits of Cika are comparable with other breeds and can be used for genetic evaluation of type traits in Cika cattle. Estimated breeding values allow adequate classification of animals in each type, which could be used for the efficient selection in the population in terms of preserving autochthonous traits.

In the light of all the facts of the historical records and due to the large differences in the type traits among individual animals in Cika population, we could not say that preserved cattle really belong to the original Cika. In the second hypothesis, we assumed that the preserved Cika is an authentic autochthonous breed which is genetically different from the Pinzgauer cattle and other breeds in the Alps.

We report a genetic characterization of Cika cattle to assess their status as autochthonous breed. Genotypes of 14 microsatellite markers in 150 Cika cattle individuals with data from 16 Central European cattle breeds were compared. It has been found that Cika cattle are genetically as diverse as other Alpine breeds, are more diverse than Austrian Simmental but less than the Balkan Buša cattle. Structure analysis showed Pinzgauer admixture in several individuals but also indicated a unique genetic identity for Cika. This analysis also allowed a selection of the most genetically pure Cika individuals as assessed by the panel of microsatellites. Cika cattle should be considered as an authentic and valuable genetic resource.

Recently, SNP genetic markers have been more and more in use. Genotyping of a large number of SNP markers (50,000 BovineSNP chip) has become a financially favourable and also provides more information about the genome. The aim of the study was to obtain unbiased estimates of the diversity parameters, the population history, and the degree of admixture in Cika cattle. Genetic analyses were performed on the genome-wide Single Nucleotide Polymorphism (SNP) array data of 76 Cika animals and 531 animals from 14 reference populations. To obtain unbiased estimates we used short haplotypes spanning four markers - instead of single SNPs to avoid an ascertainment bias of the BovineSNP50 array. Genome-wide haplotypes combined with partial pedigree and type trait scores show the potential to improve identification of purebred animals with a low degree of admixture. Phylogenetic analyses demonstrated unique genetic identity of Cika animals. Neighbour-Net distance matrix suggested long and broad phylogenetic connection between Cika and Pinzgauer. Unsupervised clustering performed by the admixture analysis and two-dimensional presentation of the genetic distances between individuals also suggest Cika is a distinct breed, despite being similar in appearance to Pinzgauer. Animals identified as the most purebred could be used as a nucleus for a recovery of the native genetic background in the current admixed population. The results show that local well-adapted strains, which have never been intensively managed and differentiated into specific breeds, exhibit large haplotype diversity. This suggests a conservation and recovery approach that does not rely exclusively on the search for the original native genetic background but also on the identification and removal of common introgressed haplotypes would be more powerful. Successful implementation of such an approach should be based on combining phenotype, pedigree, and genome-wide haplotype data of the breed of interest and a spectrum of reference breeds which potentially have had direct or indirect historical contribution to the genetic makeup of the breed of interest.

In the past Cika cattle was used mainly for milk production. Today, the milk yield of Cika cows is low compared to other breeds, which are used for the market milk production. In the breeding program it is written that Cika is a dual-purpose breed with the emphasis on milk production (Žan Lotrič et al., 2010). Now, most of the cows are kept as suckler cows in the cow-calf system, where the main product is weaned calf at the end of lactation. Povše (1894) wrote that the meat of Tolmin cattle was greatly appreciated by butchers in Trieste and Gorizia. In the third hypothesis was assumed that Cika bulls in the appropriate fattening technology are suitable for beef production and have a comparable carcass and meat quality as other dual-purpose breeds in Slovenia.

The population of Cika cattle has increased in recent years. Consequently, there were more weaned calves on the market at the end of the grazing season that were suitable for further fattening. This has led to the decision that we bought weaned calves from the breeders each year after the grazing season for several years. Weaned calves of about the same live weight and age were housed each year in autumn at the PRC (Educational Research Animal Husbandry Centre) Logatec and conducted several fattening trials.

This study aimed at comparing the effects of a traditional finishing roughage-based diet and a higher energy diet, on growth, carcass characteristics, and feeding behaviour of

Slovenian Cika and Simmental bulls (20 per breed). The experimental diets were: extensive (EXT) based on grass silage, and semi-intensive (S-INT) in which a part of the roughage was replaced with maize silage and sunflower meal. Each diet was fed *ad libitum* to 10 Cika (547 days old) and 10 Simmental (442 days old) bulls housed in group pens of five animals each. Growth performance was similar in both breeds, but Cika reached commercial finishing one month earlier than Simmental (139 *vs.* 167 days; p = 0.016). Bulls fed S-INT had higher final weight (645.3 *vs.* 590.1 kg; p = 0.05), average daily growth (1.05 *vs.* 0.83 kg; p = 0.026), and feed intake (11.7 *vs.* 10.6 kg dry matter (DM)/day; p < 0.001) than EXT bulls. Regardless of breed and diet, bulls ate 77–80% of the daily DM in the first 8h after feed delivery. Bulls fed EXT showed longer standing (406.4 *vs.* 355.8 min; p < 0.001) and eating (217.2 *vs.* 155.3 min; p < 0.001) and shorter ruminating times (77.5 *vs.* 92.9 min; p < 0.001) than S-INT bulls during the first 8 h of feed delivery. Cika bulls had lower full reticulo-rumen weights relative to slaughter weights (8.7 *vs.* 10.7%; p = 0.002) than Simmental. The positive findings obtained with Cika cattle should encourage farmers to finish their young Cika male stocks for beef production, thus contributing to the maintenance of this animal genetic resource, and also to increase the energy density of the grass-based finishing diets by feeding supplements.

Carcass and meat traits were analysed with the statistical package SAS/STAT using a GLM procedure, considering breed and diet as fixed effects. Fatty acids profile was analysed by a GLM procedure considering breed, diet and breed × diet interaction as fixed effects. Cika bulls had lower carcass weight (332.64 ± 6.63 kg) and significantly higher dressing percentage (55.79 ± 0.35%) compared to the bulls of Simmental breed (348.72 ± 6.63 kg; 54.42 ± 0.35%). Cika and Simmental young bulls had similarly light (L*) meat (35.63 ± 0.36; 35.86 ± 0.36), while Cika bulls had significantly more red (a* = 24.98 ± 0.58) and more yellow meat (b* = 11.56 ± 0.35) than Simmental (a* = 21.55 ± 0.58; b* = 9.83 ± 0.35), respectively. The dissection of right carcass sides resulted in 73.66 ± 0.37% of lean meat, 9.51 ± 0.36% of total fat, 1.48 ± 0.05% of tendons and 15.35 ± 0.21% of bones in Cika carcasses, while 73.37 ± 0.37% of lean meat, 8.20 ± 0.36 of total fat, 1.81 ± 0.05% of tendons and 16.63 ± 0.21% of bones resulted in Simmental carcasses. The breed significantly affected only the flavour among all sensory traits, where meat of Cika had more intensive flavour (5.39 ± 0.11) compared to Simmental (5.09 ± 0.12). Warner-Bratzler shear force were slightly higher in Simmental (49.32 ± 3.92 N) compared to Cika samples (43.16 ± 3.91 N) where the difference was not significant. Total intramuscular fat content was significantly higher in Cika beef (24.06 ± 1.95 g/kg) compared to Simmental (13.02 ± 1.95 g/kg) what could be explained with lower slaughter age of Simmental young bulls, regarding that the effect of the diet was not significant. Cika beef contained significantly more SFA (48.61 ± 0.36%) and less PUFA (12.65 ± 1.10%) compared to Simmental (45.28 ± 0.36%, 18.28 ± 1.10%), respectively. However, the diet did not significantly affect the percentage of SFA, MUFA, PUFA in beef of both breeds. The findings from this study show that Cika young bulls can provide meat of good quality.

Physical and chemical characteristics seem to be comparable to meat quality of Simmental and some other breeds of cattle in Europe which have already found a “local niche” for selling their products.

In this dissertation, we confirmed all three hypotheses. We confirmed that type traits are influenced by several environmental effects, which could lead to misclassification of animals in the appropriate type. Estimated heritabilities for type traits of Cika cattle are comparable with other breeds and can be used for genetic evaluation of type traits in Cika cattle. Estimated breeding values allow adequate classification of animals in each type, which could be used for efficient selection of the population in terms of preserving autochthonous traits. The genetic characterization based on microsatellite and SNP genetic markers confirmed that Cika cattle is an authentic indigenous breed in Slovenia. In accordance with the new classification based on genetic diversity, geographical proximity and breed history Cika cattle were classified in the second group of "Central-European cattle" and in the fifth subgroup "Central-Eastern breeds", where Pinzgauer and Pustertaler cattle are classified as well. Based on the genetic characterization, Cika cattle as an authentic autochthonous breed, will be recorded and presented in a new encyclopaedia of cattle breeds, published by the University of Lincoln, UK. We confirmed that young Cika bulls with an appropriate fattening technology are suitable for beef production. They achieve good carcass and meat quality, which are comparable to other dual-purpose and autochthonous breeds in Europe. The great advantage of Cika cattle is lower bones proportion in the carcass and the ability for fattening to higher slaughter weight and age, without over fatness.

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PRILOGE

Priloga A:
Obrazec za ocenjevanje zunanjosti plemenic cikastega goveda

OBRAZEC ZA OCENJEVANJE IN RAZVRŠČANJE PLEMENIC CIKASTEGA GOVEDA

Rejec:

Ime in Id.št. živali:
Datum rojstva:
Ime in Id.št. očeta:
Ime in Id.št. matere:
Zaporedna telitev in datum:

OKVIR:

Višina vihra **(cm)**	Višina križa **(cm)**	Dolžina telesa **(cm)**	Obseg prsi **(cm)**

OBLIKE:

Opisovane lastnosti	**Izraženost lastnosti (1-9)**	**Ocena**	**Napake**
Dolžina glave	dolga - kratka		-1,-2
Plemenitost glave	groba – plemenita		temen smrček I_I
Izraženost oči	slaba – močna		neustrezen pigment I_I
Debelina rogov	debeli – tanki		beli znaki na glavi I_I
Dolžina rogov	dolgi - kratki		beli znaki na nogah I_I
Usmerjenost rogov	navzven – naprej		pikasto pisana I_I
Vrat	grob – plemenit		prekinjena hrbtna lisa I_I
Izraženost podgrline	močna – slaba		hrbtna lisa na križu I_I
Pigmentacija plašča	zelo temna - zelo svetla		
Izraženost hrbtne lise	močna – slaba		
Izraženost pas na stegnih	močna – slaba		
Izraženost pas na golenih	močna – slaba		

Hrbet	uleknjen – izbočen		razplečenost I_I
Nagib križa	nadgrajen – pobit		visoko nasajen rep I_I
Kot skočnega sklepa	strm – sabljast		vdolbina med sednicama I_I
Izraženost skočnega sklepa	zadebeljen – tanek		kravja stoja I_I
Biclji	mehki - strmi		razprti parklji I_I
Parklji	nizki - visoki		

Vime pod trebuhom	majhno - obsežno		stopničasto vime I_I
Globina vimena	spuščeno - pripeto		lijakasti seski I_I
Debelina prednjih seskov	tanki - debeli		stran strleči seski I_I
Dolžina prednjih seskov	kratki - dolgi		

Čistost vimena (število)	paseski I_I medseski I_I priseski I_I	
Iztok mleka (izjava rejca)	počasen - povprečen - hiter (ocena 1-5)	
Temperament (izjava rejca)	nervozen - povprečen - miren (ocena 1-5)	

SKUPNA OCENA	AVTOHTONOST	OMIŠIČENOST	OBLIKE	VIME

TIP (obkroži)	CIKASTI	DELNI CIKASTI	PINCGAVSKI

Datum ocene:____________ Ocenjevalec: I_I_I_I_I Podpis:____________________

Priloga B:
Obrazec za ocenjevanje zunanjosti plemenskih bikov cikastega goveda

OBRAZEC ZA OCENJEVANJE IN RAZVRŠČANJE PLEMENJAKOV CIKASTEGA GOVEDA

Izvorni rejec: ____________________________ KMG-MID____________

Rejec: ________________________________ KMG-MID___________

Ime in Id.št. živali: ____________________
Datum rojstva: ____________________
Ime in Id.št. očeta: ____________________
Ime in Id.št. matere: ____________________

OKVIR:

Višina vihra **(cm)**	Višina križa **(cm)**	Dolžina telesa **(cm)**	Obseg prsi **(cm)**
Širina prsi **(cm)**	Globina prsi **(cm)**	Širina križa **(cm)**	Telesna teža **(kg)**

OBLIKE:

Opisovane lastnosti	**Izraženost lastnosti (1-9)**	**Ocena**	**Napake**
Dolžina glave	dolga - kratka		-1, -2
Plemenitost glave	groba - plemenita		temen smrček I_I
Izraženost oči	slaba – močna		neustrezen pigment I_I
Debelina rogov	debeli – tanki		beli znaki na glavi I_I
Dolžina rogov	dolgi - kratki		beli znaki na nogah I_I
Usmerjenost rogov	navzven – naprej		pikasto pisan I_I
Vrat	grob – plemenit		prekinjena hrbtna lisa I_I
Izraženost podgrline	močna – slaba		hrbtna lisa na križu I_I
Pigmentacija plašča	zelo temna - zelo svetla		
Izraženost hrbtne lise	močna – slaba		
Izraženost pas na stegnih	močna – slaba		
Izraženost pas na golenih	močna – slaba		

Hrbet	uleknjen – izbočen		razplečenost I_I
Nagib križa	nadgrajen – pobit		visoko nasajen rep I_I
Kot skočnega sklepa	strm – sabljast		
Izraženost skočnega sklepa	zadebeljen – tanek		kravja stoja I_I
Biclji	mehki - strmi		razprti parklji I_I
Parklji	nizki - visoki		

Temperament (izjava rejca)	nervozen - povprečen - miren (ocena 1-5)	

SKUPNA OCENA	AVTOHTONOST	OMIŠIČENOST	OBLIKE
TIP (obkroži)	CIKASTI	DELNI CIKASTI	PINCGAVSKI

NAMEN UPORABE BIKA: ______________________________
OBDOBJE PRIZNANJA: ______________________________

Datum ocene:__________ Komisija za oceno in odbiro bikov:

Priloga C:

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Simčič, Mojca

Od: one_production <one_production@plos.org>
Poslano: 13. marec 2015 21:36
Za: Simčič, Mojca; ivica.medjugorac@gen.vetmed.uni-muenchen.de
Zadeva: PONE-D-14-24065R2 ref:_00DU0Ifis._500U0IKIF [ref:_00DU0Ifis._500U0IKIF0:ref]
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I have also included a formal acceptance letter to this email if it helps Dr. Simcic with her thesis project. If there is anything else I can assist with, please let me know.

Kind regards,
Saziya

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Priloga E:
Licenčna pogodba za uporabo članka v tiskani in elektronski verziji disertacije 3

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Animal Production Science **Manuscript No.** AN13095

Title of the paper (the 'Work') Effects of finishing diets on growth, slaughter performance and feeding behaviour of Slovenian autochthonous Cika and Simmental young bulls

Author(s) Žgur, Silvester; Simčič, Mojca; Petrič, Nežika; Čepon, Marko; Brscic, Marta; Cozzi, Giulio.

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