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NEOLITHIC TRANSITION TO FARMING IN NORTHERN ADRIATIC. LACTOSE TOLERANCE, DAIRYING AND LIPID BIOMARKERS ON POTTERY

In this paper, we discuss the Neolithic transition to farming in Northern Adriatic, lactose tolerance, dairying and lipid biomarkers on pottery. While archaeological and biochemical data suggest that dairying was adopted in the Neolithic in Europe, archaeogenetic data show the absence of the allelic variant –13910*T and zero persistence in Neolithic populations in Europe. The Mala Triglavca case study shows that the Early Neolithic economy in the Caput Adriae region was mixed. It consisted of milk and processed milk, meat animal products, freshwater fish and various plants. The Vlaška group herders managed a broader spectrum of resources than exclusively ovicaprids, and were able to produce a wide range of low-lactose, storable products by fermenting milk.

KEY WORDS: *Adriatic Neolithic, Vlaška culture, demic diffusion, transition to farming, dairying, lactase persistence, lipids, pottery*

INTRODUCTION

Dairying and lactose tolerance marked by the –13910*T allele (lactase gene) in modern European populations are thought to have evolved in a relatively short period within the transition to farming and "at the front of the demic diffusion" and were introduced to Europe by lactase-persistent farmers.[1]

1 Y. ITAN *et alii*, 2009, 7; see also Y. ITAN *et alii*, 2010; J. BURGER, M. G. THOMAS, 2011; P. GERBAULT *et alii*, 2011; M. LEONARDI *et alii*, 2012; for discussion see M. BUDJA *et alii*, 2013.

NEOLITIČKI PRIJELAZ NA ZEMLJORADNJU NA SJEVERNOM JADRANU. TOLERANCIJA LAKTOZE, MLJEKARSTVO I LIPIDNI BIOMARKERI NA KERAMICI

U ovom se radu razmatra neolitički prijelaz na zemljoradnju na sjevernom Jadranu, tolerancija laktoze, mljekarstvo i lipidni biomarkeri na keramici. Iako arheološki i biokemijski podaci ukazuju da je mljekarstvo bilo prihvaćeno u neolitiku u Europi, arheogenetički podaci otkrivaju nedostatak alelske varijante –13910*T i nultu perzistenciju kod europskih neolitičkih populacija. Istraživanje na primjeru Male Triglavce pokazuje da je ranoneolitička privreda bila miješanog tipa u prostoru *Caput Adriae*. Sastojala se od mlijeka i mliječnih proizvoda, životinjskih mesnih proizvoda, slatkovodne ribe i raznih biljaka. Stočari vlaške kulture su raspolagali širim spektrom resursa osim ovaca i koza i mogli su fermentiranjem mlijeka proizvesti niz trajnih proizvoda s malim udjelom laktoze.

KLJUČNE RIJEČI: *neolitik na Jadranu, vlaška kultura, demička difuzija, prijelaz na zemljoradnju, mljekarstvo, laktazna perzistencija, lipidi, keramika*

UVOD

Mljekarstvo i tolerancija laktoze označena alelom –13910*T (gen za laktazu) u suvremenim europskim populacijama, smatra se, razvili su se u relativno kratkom roku u sklopu prijelaza na zemljoradnju i "na čelu demičke difuzije" te su ih u Europu donijeli zemljoradnici s perzistencijom laktaze.[1]

1 Y. ITAN *et alii*, 2009, 7; vidi također Y. ITAN *et alii*, 2010; J. BURGER, M. G. THOMAS, 2011; P. GERBAULT *et alii*, 2011; M. LEONARDI *et alii*, 2012; za raspravu vidi M. BUDJA *et alii*, 2013.

THE TRANSITION TO FARMING AND THE TRANSITION TO MILK CULTURE

All humans have the lactase gene, but only children produce lactase in sufficient amounts to break down lactose, the main sugar in milk. Fresh milk is a toxin to adults without lactase, and often causes symptoms such as abdominal pain, bloating, flatulence and diarrhoea. Lactase is an enzyme produced in the digestive system of mammalian infants, but is dramatically reduced after the weaning period. The ability to digest lactose found in fresh milk is called lactase persistence. However, the correlation between lactase persistence and fresh milk consumption is not yet fully understood.

The lactase persistence trait is found in approx. 35% of adults in human populations in the world, but varies widely between and within continents. The frequencies of lactase-persistent individuals are generally high in Europe, Central Asia and India but almost zero in Southeast Asia.[2] In Europe, lactase persistence is at its highest frequency in the North, with a decreasing cline from the central and western (62–86%) to the southern and eastern regions (15–54%).[3] On the Indian sub-continent the frequency of lactase persistence is higher in the North-West than elsewhere; further East, the lactase persistence frequency is generally low. In Africa and the Middle East, the distribution is patchy, with some pastoral nomadic tribes having high frequencies (92%) of lactase persistence compared with neighbouring groups living in the same region.[4]

A number of single nucleotide polymorphisms that allow lactase to be produced into adulthood have different geographic distributions within the modern populations. The derived allelic variant –13910*T of the first nucleotide cytosine to thymine transition is associated with lactase persistence in Europe, Central Asia and India.[5] This allele and associated selection for lactose tolerance seems to originate twice in ancestral populations (bearing haplotypes H) in regions north of the Caucasus and West of the Urals. The first origin is estimated at 12 000 to 5000 BP, and the second more recently at 3000 to 1400 years ago. It was suggested that the frequency gradient in modern populations shows

2 Y. ITAN *et alii*, 2010; P. GERBAULT *et alii*, 2011.

3 P. GERBAULT *et alii*, 2011, 864.

4 S. A. TISHKOFF *et alii*, 2007; C. J. E. INGRAM *et alii*, 2009; P. GERBAULT *et alii*, 2011.

5 N. S. ENATTAH *et alii*, 2002; C. J. E. INGRAM *et alii*, 2007; Y. ITAN *et alii*, 2009.

PRIJELAZ NA ZEMLJORADNJU I PRIJELAZ NA KULTURU MLIJEKA

Svi ljudi imaju gen za laktazu, ali samo djeca proizvode laktazu u dovoljnim količinama da razgradi laktozu, osnovni šećer u mlijeku. Svježe mlijeko je toksično za odrasle pojedince bez laktaze i često izaziva simptome kao što su bol u abdomenu, nadutost i proljev. Laktaza je enzim koji se stvara u probavnom sustavu mladunčadi sisavaca, ali joj se količina osjetno smanjuje nakon završetka laktacije. Sposobnost probavljanja laktoze, koja se nalazi u svježem mlijeku, naziva se perzistencija laktaze. Veza između perzistencije laktaze i konzumacije svježeg mlijeka još nije u potpunosti objašnjena.

Perzistenciju laktaze nalazimo kod otprilike 35% odraslih ljudi na svijetu, sa značajnim varijacijama između kontinenata i unutar pojedinih kontinenata. Više pojedinaca s perzistencijom laktaze ima u Europi, središnjoj Aziji i Indiji, a gotovo ih uopće nema u jugoistočnoj Aziji.[2] U Europi je perzistencija laktaze najčešća na sjeveru, opadajući od centralnih i zapadnih (62–86%) do južnih i istočnih predjela (15–54%).[3] Na indijskom potkontinentu učestalost perzistencije laktaze je veća na sjeverozapadu nego u drugim krajevima. Dalje na istok perzistencija laktaze je općenito rjeđa. U Africi i na Srednjem istoku rasprostranjenost je neujednačena. Neka nomadska plemena iskazuju visoku pojavnost (92%) perzistencije laktaze u usporedbi sa susjednim grupama koje žive u istoj regiji.[4]

Veliki broj jednostrukih nukleotidskih polimorfizama koji omogućuju da se laktaza nastavi proizvoditi i u odrasloj dobi pokazuje različitu geografsku rasprostranjenost kod suvremenih populacija. Izvedena alelska varijanta –13910*T prvog nukleotidskog prijelaza s citozina na timin je povezana s perzistencijom laktaze u Europi, središnjoj Aziji i Indiji.[5] Čini se da ovaj alel i povezana selekcija za toleranciju laktoze imaju dvostruko porijeklo u ancestralnim populacijama (koje imaju haplotip B) u područjima sjeverno od Kavkaza i zapadno od Urala. Starije se datira od 12000 do 5000 godina prije sadašnjosti, a drugo, mlađe, od 3000 do 1400 godina prije sadašnjosti. Pretpostavlja se da stopa pojavljivanja kod suvremenih populacija pokazuje

2 Y. ITAN *et alii*, 2010; P. GERBAULT *et alii*, 2011.

3 P. GERBAULT *et alii*, 2011, 864.

4 S. A. TISHKOFF *et alii*, 2007; C. J. E. INGRAM *et alii*, 2009; P. GERBAULT *et alii*, 2011.

5 N. S. ENATTAH *et alii*, 2002; C. J. E. INGRAM *et alii*, 2007; Y. ITAN *et alii*, 2009.

that the allele migrated to the West.[6] Lactase persistence in Africa is linked to three single nucleotide polymorphisms, C–14010, G–13915 and G–13907, close to the lactase gene.[7] They are linked to different ethnic groups with divergent haplotype backgrounds and geographic regions. However, some questions still remain unanswered. The Hadza people in Tanzania show a high level of lactase persistence despite having nothing to do with herding.

Lactase persistence is one of the leading examples of natural selection in humans and also one of the first clear examples of the polymorphism of a regulatory in the human genome.[8] A single gene was involved with different mutations in different parts of the world, but with similar effects. The lactase persistence has been mainly identified in pastoralist populations and, as fresh milk and milk products are the only known naturally occurring sources of lactose, it is therefore unlikely that this trait would be selected without a supply of fresh milk.[9]

Several scenarios relating to the "selection hypotheses on lactase persistence" and to "the advantage of being lactase persistent" have been discussed recently.[10] The first "gene – culture coevolution" or "culture historical" hypothesis proposes that lactase persistence was selected among populations that consumed milk over generations and adopted animal breeding and dairying, thereby increasing the dependence of adults on milk. In opposition, the second, the "reverse cause hypothesis", suggests that dairying was adapted by populations that were already lactase persistent. A mutation associated with lactase persistence within small human groups could have grown in frequency through genetic drift before milk was introduced into subsistence. The third, the "calcium assimilation hypothesis", suggests that in high-latitude environments where lower sunlight produces less vitamin D (important for the absorption of calcium in bones) lactose in fresh milk promotes the uptake of calcium present in milk. In contrast to hunter-gatherers who had a vitamin D rich diet abundant in marine food, early agriculturalist might have had problems with vitamin D deficiency, and drinking milk could have been an advantage for lactase-persistent farmers. The fourth, the "arid climate hypothesis", suggests that in regions where

6 N. S. ENATTAH, 2007, 619-622.

7 S. A. TISHKOFF *et alii*, 2007.

8 C. J. E. INGRAM *et alii*, 2009.

9 P. GERBAULT *et alii*, 2011, 864.

10 For details see M. BUDJA *et alii*, 2013.

da je alel migrirao na zapad.[6] Perzistencija laktaze u Africi je povezana s tri jednostruka nukleotidna polimorfizma koji su bliski genu laktaze: C–14010, G–13915 i G–13907.[7] Povezani su s različitim etničkim grupama s divergentnim porijeklom haplotipova i s različitim regijama. Ipak, na neka pitanja još nema odgovora. Pleme Hadza u Tanzaniji ima visok nivo perzistencije laktaze iako nemaju nikakve veze sa stočarstvom.

Perzistencija laktaze je jedan od vodećih primjera prirodne selekcije kod ljudi i jedan od prvih jasnih primjera polimorfizma regulatora u ljudskom genomu.[8] Radi se o jednom genu s različitim mutacijama u raznim dijelovima svijeta, ali sa sličnim učincima. Perzistencija laktaze se uglavnom nalazi kod stočarskih populacija a s obzirom na to da su svježe mlijeko i mliječni proizvodi jedini poznati prirodni izvori laktoze, nije vjerojatno da bi se ova karakteristika održala bez opskrbe svježim mlijekom.[9]

Nekoliko je scenarija u vezi sa "selekcijskim hipotezama o perzistenciji laktaze" i "prednostima perzistencije laktaze".[10] Prema prvoj hipotezi o "gensko-kulturnoj koevoluciji" ili "kulturno povijesnoj" hipotezi perzistencija laktaze se događa među populacijama koje su konzumirale mlijeko kroz generacije i prihvatile uzgoj stoke i mljekarstvo, povećavajući na taj način ovisnost odraslih pojedinaca o mlijeku. Nasuprot tome, prema drugoj hipotezi "obrnutog razloga" mljekarstvo su prihvatile populacije koje su već imale perzistenciju laktaze. Mutacija povezana s perzistencijom laktaze unutar malih ljudskih grupa mogla se povećavati kroz genski drift prije nego što je mlijeko uvedeno u prehranu. Prema trećoj hipotezi "asimilacije kalcija" u ambijentima većih geografskih širina gdje manje sunčeve svjetlosti proizvodi manje vitamina D (važnog za apsorpciju kalcija u kostima), laktoza u svježem mlijeku olakšava unos kalcija zastupljenog u mlijeku. Za razliku od lovaca i sakupljača čija je prehrana bila bogata vitaminom D zbog obilja namirnica iz voda, rani zemljoradnici su mogli imati problema s nedostatkom vitamina D, a konzumacija mlijeka je mogla biti prednost za zemljoradnike s perzistencijom laktaze. Prema četvrtoj hipotezi "suhe klime" u ovim regijama je vladala oskudica vode pa je mlijeko moglo

6 N. S. ENATTAH, 2007, 619-622.

7 S. A. TISHKOFF *et alii*, 2007.

8 C. J. E. INGRAM *et alii*, 2009.

9 P. GERBAULT *et alii*, 2011, 864.

10 Za detalje vidi M. BUDJA *et alii*, 2013.

water was scarce, milk could be an uncontaminated source of fluid used by pastoralists. While lactase non-persistent individuals were at risk from diarrhoea and the dehydrating effects of drinking fresh milk, the selection may have been strong in lactase-persistent individuals.

The beginning of dairy culture can be assumed to have occurred in the processes of the transition to farming, and the utilisation of lactic acid bacteria can be traced alongside the domestication of sheep, goat and cattle. In milking and milk processing, the lactococci and lactobacilli were manipulated to initiate the fermentation that converts milk into yogurt, buttermilk, butter and cheese. These have advantages in storing and transporting dairy products and making them available in times of low milk production on one hand, and making milk available as a nutritional source throughout the entire life of the individuals on the other.

It should be noted that lactose is progressively reduced by milk processing. The fermented milk products cause fewer or no mal-symptoms to lactase non-persistent individuals. While the lactose content of fresh milk ranges between 4.42–5.15 g/g% in cattle, 4.66–4.82 g/g% in goats and 4.57–5.40 g/g% in sheep, it can be reduced to 50–60% by bacterial fermentation. Some processed milk products (such as cheese and butter) have very low lactose content, ranging from 0–3.7 g/g%.[11]

We may assume that animal domestication in Neolithic brought milk into the diet, and that domestic animals were a more stable seasonal resource, which could became an alternative to hunter-gatherers' system of the seasonal exploitation of a broad spectrum of animal resources. Milk is a good source of calories, specifically an important source of protein and fat, and must have increased the quality of the diet. The milk production of a prehistoric cow has been estimated to range between 400 and 600kg per weaning period. Even when the milk necessary for the raising of the calves is subtracted, some 150–250kg remains. This is almost equivalent to the calorie gain from the meat of a whole cow. Over the years, milking thus may have resulted in a greater energy yield than the use of cattle for meat.[12] Dairying was especially important for children and adolescents as it prolongs the beneficial effects of milk (proteins, fats, but also calcium supply) long after weaning.[13]

11 D. NAGY *et alii*, 2011, 267; A. LIEBERT, 2012, 77.

12 P. GERBAULT *et alii*, 2011, 865-866.

13 J.-D. VIGNE, 2008, 200; P. S. PANESAR, 2011.

biti izvor nezagađene tekućine za stočare. Dok su pojedinci bez perzistencije laktaze bili u opasnosti od proljeva i dehidracije ako su pili svježe mlijeko, selekcija je mogla biti u korist pojedinaca s perzistencijom laktaze.

Vjerojatno se početak mljekarske kulture dogodio tijekom procesa prijelaza na zemljoradnju, a korištenje bakterija mliječne kiseline može se pratiti usporedo s pripitomljavanjem ovce, koze i goveda. U mužnji i obradi mlijeka, laktokoki i laktobacili se koriste da bi inicirali fermentaciju koja mijeko pretvara u jogurt, mlaćenicu, maslac i sir čije su prednost trajnost i lakši transport. S jedne strane, u doba manje produkcije mlijeka bili su dostupni mliječni proizvodi, a s druge, mlijeko je postalo nutritivni izvor za cijeli život.

Valja spomenuti da se laktoza progresivno smanjuje obradom mlijeka. Fermentirani mliječni proizvodi izazivaju manje ili uopće ne izazivaju simptome kod pojedinaca koji nemaju perzistenciju laktaze. Sadržaj laktoze u svježem mlijeku varira između 4.42–5.15 g/g% kod goveda, 4.66–4.82 g/g% kod koza i 4.57–5.40 g/g% kod ovaca, a može se smanjiti za 50–60% bakterijskom fermentacijom. Neki proizvodi od obrađenog mlijeka (kao maslac i sir) imaju vrlo mali udio laktoze koji varira između 0–3.7 g/g%.[11]

Može se pretpostaviti da je domestikacija životinja u neolitiku uvela mlijeko u prehranu i da su domaće životinje bile stabilniji sezonski resurs koji je mogao postati alternativa sakupljačko-lovačkom sustavu sezonskog korištenja širokog spektra životinjskih resursa. Mlijeko je dobar izvor kalorija i posebno dobar izvor proteina i masti te je moralo poboljšati ishranu. Mliječna produkcija krave u prapovijesti procjenjuje se na 400-600 kg za jedan laktacijski period. Kad se od te količine oduzme mlijeko potrebno za othranjivanje teladi, ostaje 150–250 kg što je gotovo ekvivalent kalorijske vrijednosti mesa cijele krave. Kroz godine, mužnja mlijeka mogla je rezultirati većim energetskim prinosom nego što se dobivalo od mesa.[12] Mljekarstvo je bilo posebno važno za djecu i adolescente jer produžuje povoljne učinke mlijeka (unos proteina, masti, ali i kalcija) dugo nakon laktacije.[13]

11 D. NAGY *et alii*, 2011, 267; A. LIEBERT, 2012, 77.

12 P. GERBAULT *et alii*, 2011, 865-866.

13 J.-D. VIGNE, 2008, 200; P. S. PANESAR, 2011.

However, the absence of lactase gene (e.g., the allelic variant –13910*T) in Neolithic populations in Europe shows that lactase persistence was very low and "may have even been zero".[14] On the contrary, the analyses of dairy fats in pottery suggest that milking, milk consumption and processing were widely adopted in the Neolithic in Eurasia. Biomolecular analyses of the lipids present in food which become absorbed and trapped in the pores of clay vessels indeed show evidence of dairy production in southwest Asia as early as c.7000 calBC. The apparent intensification of dairy processing in northwest Anatolia at 6500-5500 calBC was recognised as an early centre for milk processing, with cow's milk as the main source of dairy products in this region.[15] However, degraded ruminant fatty acid in pottery suggest milk products and milk processing (*i.e.* the heating of milk) in the Starčevo-Criş culture at *c.* 5950–5500 calBC and Köros culture at *c.* 5800–5700 calBC.[16] In Northern Adriatic in Vlaška culture context (Mala Triglavca) it was found that 30% of sampled pottery contain lipids characteristic of dairy fats thus indicating that the processing of dairy products in pottery vessels was quite extensive. The pottery samples are well embedded in the time span 5467–5227 calBC.[17] In Northern Europe in the Early Neolithic LBK complex the milk processing is dated to *c.* 5200 and 4900–4800 calBC.[18]

Ipak, nedostatak gena laktaze (npr. alelske varijante –13910*T) u neolitičkim populacijama u Europi pokazuje da je perzistencija laktaze bila vrlo niska ili čak nepostojeća.[14] Nasuprot tome, analiza mliječnih masti na keramici ukazuje da je mužnja, potrošnja i obrada mlijeka bila široko prihvaćena u neolitiku u Euraziji. Biomolekularne analize lipida iz hrane koji se upijaju i ostaju u porama zemljanih posuda pokazuju da je postojala mliječna proizvodnja na jugozapadu Azije već oko 7000 kal. god. pr. Kr. Sjeverozapadna Anadolija prepoznata je, zbog očitog intenziviranja obrade mlijeka oko 6500-5500 kal. god. pr. Kr., kao rani centar obrade mlijeka s kravljim mlijekom kao glavnim izvorom mliječnih proizvoda u toj regiji.[15] Raspadnute preživačke masne kiseline ukazuju na mliječne proizvode i obradu mlijeka (odnosno zagrijavanje mlijeka) u kulturi Starčevo-Criş oko 5950–5500 kal. god. pr. Kr. i kulturi Köros oko 5800–5700 kal. god. pr. Kr.[16] Na sjevernom Jadranu u kontekstu vlaške kulture (Mala Triglavca) otkriveno je da 30% analizirane keramike sadrži lipide karakteristične za masti mliječnih proizvoda pokazujući da je obrada mliječnih proizvoda u keramičkim posudama bila prilično česta. Uzorci keramike pripadaju vremenskom periodu 5467–5227 kal. god. pr. Kr.[17] U sjevernoj Europi u ranom neolitiku kompleksa linearno-trakaste keramike obrada mlijeka se datira oko 5200 i 4900–4800 kal. god. pr. Kr.[18]

THE LACTASE PERSISTENCE PARADOX

Parallel archaeogenetic studies hypothesised that a single mutation (–13910*T) in the human genome which allow adults to consume fresh milk evolved within a group(s) of Neolithic pioneer stockbreeders among whom lactase persistence was rare, but who initially practised dairying in Southeast Europe in the middle of 8th millennium BP and later migrated towards central and northern Europe to an area inhabited by foragers. They reached the northern Adriatic at *c.* 7400 BP.[19]

PARADOKS PERZISTENCIJE LAKTAZE

Prema paralelnim arheogenetičkim studijama jedna mutacija (–13910*T) u ljudskom genomu zbog koje odrasli pojedinci mogu konzumirati svježe mlijeko razvila se unutar grupe (grupa) prvih neolitičkih uzgajivača stoke među kojima je perzistencija laktaze bila rijetka, ali koji su se originalno bavili mljekarstvom u jugoistočnoj Europi sredinom 8. tisućljeća prije sadašnjosti i kasnije migrirali prema srednjoj i sjevernoj Europi na područja naseljena sakupljačko-lovačkim zajednicama. Došli su i do sjevernog Jadrana oko 7400 god. prije sadašnjosti.[19]

14 M. LEONARDI *et alii*, 2012, 93.

15 R. P. EVERSHED *et alii*, 2008; L. THISSEN *et alii*, 2010; for comments see C. ÇAKIRLAR, 2012.

16 O. E. CRAIG *et alii,* 2005.

17 M. BUDJA *et alii*, 2013, 106-112.

18 M. SALQUE *et alii*, 2012.

19 P. GERBAULT *et alii*, 2009; P. GERBAULT *et alii*, 2011; J. BURGER, M. G. THOMAS, 2011; P. GERBAULT, 2012.

14 M. LEONARDI *et alii*, 2012, 93.

15 R. P. EVERSHED *et alii*, 2008; L. THISSEN *et alii*, 2010; za komentare vidi C. ÇAKIRLAR, 2012.

16 O. E. CRAIG *et alii,* 2005.

17 M. BUDJA *et alii*, 2013, 106-112.

18 M. SALQUE *et alii*, 2012.

19 P. GERBAULT *et alii*, 2009; P. GERBAULT *et alii*, 2011; J. BURGER, M. G. THOMAS, 2011; P. GERBAULT, 2012.

Pascale Gerbault *et al.*[20] and Yuval Itan *et al.*[21] intensively studied the evolutionary processes that shaped the European lactase persistence patterns in modern populations. They ran computer simulations to test different selection hypotheses on lactase persistence in relation to demic diffusion and culture diffusion models. Their results are contrasting. Computer simulations showed that high lactase persistence frequencies observed in Northern and Western Europe can be explained by selective pressure, possibly increasing with latitude in a way that is highly compatible with the calcium assimilation hypothesis combined with the effect of demographic expansion (*i.e.* population growth) during the Neolithic transition. The much lower frequencies in Southeast Europe can be explained by genetic drift if this mutation was carried by Near-eastern pioneers. Keeping in mind that the demic diffusion model is based on the decreasing southeast-northwest cline of frequencies for selected Y-chromosome markers, indicating the movement of Neolithic men with Levantine genetic ancestry across Europe, it is important to note that the allelic variant −13910*T cline travels in the opposite direction. However, computer modelling suggests that the centre of distribution of an allele can be far removed from its location of origin in the direction of population expansion, moving at the front of the demic diffusion. This process is called "allele surfing" and is thought to have occurred with the spread of farmers in Europe[22] thus hypothesised that strong selection for lactase persistence runs within the "niche construction" at the front of the demic diffusion, where local environmental condition and subsistence strategies led to population increase and concentration on milk resources. The initial selection was embedded in Southeast Europe at 8518±66 BP (7592–7528 calBC), and the first lactase persistent farmers and domesticates arrived in Central Europe and the Northern Adriatic a millennium later, at 7416±101 BP (6418–6213 calBC). The latter ^{14}C date was contextualised in the Edera/Stenašca rock shelter in the Trieste Karst and is linked to the Early Neolithic Vlaška culture (Fig. 1).[23] Nevertheless, Itan *et al.*[24] suggest that the −13910*T allele first underwent selection in a relatively short period

Pascale Gerbault *et alii*[20] i Yuval Itan *et alii*[21] su intenzivno proučavali evolucijske procese koji su oblikovali europske obrasce perzistencije laktaze u suvremenim populacijama. Pomoću računalnih simulacija ispitivali su razne selekcijske hipoteze u vezi s perzistencijom laktaze u odnosu na demičku difuziju i modele kulturne difuzije. Njihovi su rezultati u opreci. Računalne simulacije su pokazale da češća perzistencija laktaze primijećena u sjevernoj i zapadnoj Europi može biti objašnjena selekcijskim pritiskom koji se možda povećavao s geografskom širinom na način koji je kompatibilan s hipotezom asimilacije kalcija u kombinaciji s efektom demografske ekspanzije (tj. rastom populacije) tijekom neolitičkog prijelaza. Puno manja učestalost u jugoistočnoj Europi može se objasniti genskim driftom, ako su ovu mutaciju nosili bliskoistočni pioniri. Ako imamo na umu da se model demičke difuzije temelji na smanjenju jugoistočno-sjeverozapadne učestalosti izabranih markera Y-kromosoma, što ukazuje na kretanja ljudi u neolitiku s levantinskim genskim porijeklom širom Europe, važno je primijetiti da se pad alelske varijante −13910*T kreće u drugom smjeru. Računalni modeli ukazuju da centar distribucije alela može biti prilično udaljen od svog ishodišta u smjeru populacijskog širenja, krećući se na čelu demičke difuzije. Ovaj proces se naziva "surfanje alela" i smatra se da se pojavio zajedno sa širenjem zemljoradnika u Europi.[22] Pretpostavlja se da se jaka selekcija za perzistenciju laktaze javlja unutar "konstrukcije niše" na čelu demičke difuzije gdje su lokalni ambijentalni uvjeti i strategije preživljavanja doveli do rasta stanovništva i koncentracije na mliječne resurse. Inicijalna se selekcija dogodila u jugoistočnoj Europi oko 8518±66 prije sadašnjosti (7592.–7528. kal. god. pr. Kr.), a prvi zemljoradnici s perzistencijom laktaze i domesticiranim životinjama su došli u srednju Europu i na sjeverni Jadran tisućljeće kasnije, oko 7416±101 prije sadašnjosti (6418.–6213. kal. god. pr. Kr.). Ovaj ^{14}C datum je kontekstualiziran na nalazištu Edera/Stenašca u Tršćanskom Krasu i povezan je s ranoneolitičkom vlaškom kulturom[23] (Sl. 1). Ipak, Itan *et alii*[24] predlažu da je alela −13910*T prošla selekciju u relatvno kratkom periodu među zem-

20 P. GERBAULT *et alii*, 2009; P. GERBAULT *et alii*, 2011; P. GERBAULT *et alii*, 2012.

21 Y. ITAN *et alii*, 2009; Y. ITAN *et alii*, 2010.

22 P. GERBAULT *et alii*, 2009, 3, 7-8, Fig. 1; P. GERBAULT *et alii*, 2011; see also P. GERBAULT, 2012, 179-198, Fig. 4.

23 R. PINHASI *et alii*, 2005, supporting information: Tab. 1.

24 Y. ITAN *et alii*, 2009; Y. ITAN *et alii*, 2010; see also J. BURGER, M. G. THOMAS, 2011; M. LEONARDI *et alii*, 2012.

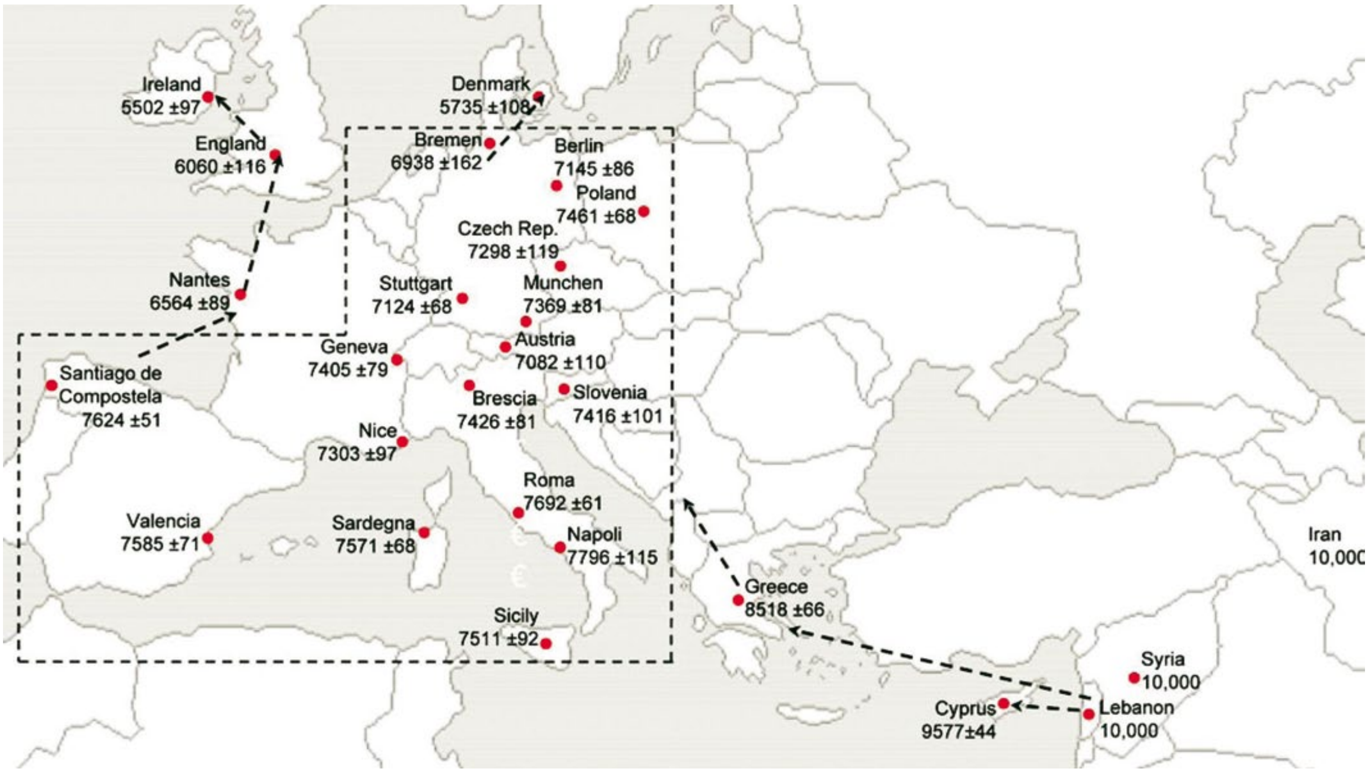
20 P. GERBAULT *et alii*, 2009; P. GERBAULT *et alii*, 2011; P. GERBAULT *et alii*, 2012.

21 Y. ITAN *et alii*, 2009; Y. ITAN *et alii*, 2010.

22 P. GERBAULT *et alii*, 2009, 3, 7-8, Fig. 1; P. GERBAULT *et alii*, 2011; vidi još P. GERBAULT, 2012, 179-198, Fig. 4.

23 R. PINHASI *et alii*, 2005, dodatne informacije: Tab. 1.

24 Y. ITAN *et alii*, 2009; Y. ITAN *et alii*, 2010; vidi još J. BURGER, M. G. THOMAS, 2011; M. LEONARDI *et alii*, 2012.



SL. 1. / FIG. 1.

Map location of European and Near-Eastern populations used for the computer simulation test of gene-culture coevolution and calcium assimilation hypotheses of lactase gene selection. It implies that the genes of the first farmers travelled over Europe within the Neolithic demic diffusion (from P. GERBAULT *et alii*, 2009, Fig 1).

Karta s prikazom raširenosti europskih i bliskoistočnih populacija koja je korištena za testnu računalnu simulaciju hipoteza gensko-kulturne koevolucije i asimilacije kalcija u selekciji gena laktaze. Pretpostavka je da su se geni prvih zemljoradnika kretali Europom u sklopu neolitičke demičke difuzije (prema P. GERBAULT et alii, 2009, sl. 1).

among dairy farmers in the northern Balkans in the Starčevo and Körös cultures. It was than dispersed by demic diffusion to Central and Western Europe in the area of Linear Pottery culture at "around 6256–8683 years BP".[25] However, both scenarios, the demic diffusion of lactase-persistent farmers across Europe and the evolution of lactase persistence in Central Europe in the Neolithic, seem to be unrealistic. The archaeogenetic analysis of Neolithic skeletons suggests that "*lactase persistence frequency was significantly lower in early Neolithic Europeans than it is today, and may have been zero*".[26] Indeed, the analysis revealed an absence of the –13910*T allele in Central Europe, in the Western Mediterranean and the Baltic in Mesolithic and Neolithic populations.[27] The only exceptions are two post-Neolithic individuals in the Basque Country on the Iberian Peninsula.[28]

ljoradnicima-mljekarima na sjevernom Balkanu u kulturama Starčevo i Körös. Nakon toga, proširila se demičkom difuzijom na srednju i zapadnu Europu u području linearne keramike oko 8683.-6256. god. prije sadašnjosti.[25] Ipak, čini se da su oba scenarija (demička difuzija zemljoradnika s perzistencijom laktaze širom Europe i evolucija perzistencije laktaze u srednjoj Europi u neolitiku) nerealna. Arheogenetičke analize neolitičkih kostura ukazuju da je "*učestalost perzistencije laktaze dosta niža kod ranoneolitičkih Europljana nego što je danas, i da bi mogla čak biti nepostojeća*".[26] Analize su pokazale nedostatak alela –13910*T u srednjoj Europi, zapadnom Mediteranu i na Baltiku kod mezolitičkih i neolitičkih populacija.[27] Jedine iznimke su dva post-neolitička pojedinca u Baskiji na Iberskom poluotoku.[28]

25 Y. ITAN *et alii*, 2009, 7; see also Y. ITAN *et alii*, 2010.

26 M. LEONARDI *et alii*, 2012, 93; see also J. BURGER, M. G. THOMAS, 2011.

27 J. BURGER *et alii*, 2007; J. BURGER, M. G. THOMAS, 2011; M. LACAN *et alii*, 2011; A. LINDERHOLM, 2011; D. NAGY *et alii*, 2011.

28 T. S. PLANTINGA *et alii*, 2012.

25 Y. ITAN *et alii*, 2009, 7; vidi još Y. ITAN *et alii*, 2010.

26 M. LEONARDI *et alii*, 2012, 93; see also J. BURGER, M. G. THOMAS, 2011.

27 J. BURGER *et alii*, 2007; J. BURGER, M. G. THOMAS, 2011; M. LACAN *et alii*, 2011; A. LINDERHOLM, 2011; D. NAGY *et alii*, 2011.

28 T. S. PLANTINGA *et alii*, 2012.

Biomolecular analyses of dairy fats in Neolithic pottery suggest that milking, milk consumption and processing were widely adopted in the Neolithic in Europe before the lactase persistence arose or became frequent. We may assume, therefore, that under normal circumstances lactase persistence is not necessarily to be under very strong selection in this population and fits with the hypothesis that dairying and milk consumption emerged before genetic adaptation.

EARLY FARMING IN NORTHERN ADRIATIC

The distribution of the first farming communities in the Eastern Adriatic is traditionally associated with the "Impresso Cardium" (*i.e.* impressed) pottery dispersal and demic diffusion migratory model.

It was also used as an indicator of the spread of farming across the region. Stašo Forenbaher and Preston Miracle[29] introduced a two-phase model suggesting that impressed ware originated in coastal Northern Greece and spread with immigration from South to North along the Adriatic coast. The process included immigrant farmers that made exploratory visits and set up short-term seasonal camps at caves and open-air sites along the coastal strip of southern Dalmatia (*i.e.* pioneer colonisation), followed by a village settlement that spread slowly towards the Northern Adriatic in areas with fertile soils (*i.e.* consolidation phase). The available radiocarbon data sets do not confirm the gradual colonisation model as there is no essential chronological difference in impressed pottery appearance and dispersal in southern and northern Adriatic[30] (Fig. 2).[31] The beginning of the Early Neolithic in the Eastern Adriatic appears to be embedded in the time span between 6048–5988 calBC in the North (Vela spilja, Lošinj Island), 5985–5843 calBC in

29 S. FORENBAHER, P. MIRACLE, 2005; S. FORENBAHER, P. MIRACLE, 2006.

30 S. FORENBAHER *et alii*, 2013.

31 The recently published ^{14}C dates are: 7134±37 BP (OxA–18118) for Vela spilja, Lošinj Island; 7000±100 BP (lab code unavailable), for Kargadur 6769±33 BP, 6612±32 (OxA–21092, OxA–21093) and Vižula 6140±70 (HD–11733) on the southern tip of Istria peninsula, and 6999±37 BP (OxA–17194) for Pokrovnik in Dalmatia; 7050±37 (OxA–18120) for Spila Nakovana on Pelješac Peninsula; and 7000±120 (Z–1968) for Vela spila (C. BONSAL *et alii*, 2013, 149, Tab. 8.1; S. FORENBAHER *et alii*, 2013, Tab. 1). A date from Vela spila, originally published as related to early "Impresso Cardium" pottery 7300±120 BP, Z–1967, has recently been reattributed to a "Mesolithic/Neolithic transitional period" (S. FORENBAHER *et alii*, 2013, 597). The dates are calibrated at 68.2 probability using the Oxcal 4.2 program.

Biomolekularne analize mliječnih masti na neolitičkoj keramici ukazuju da su mužnja, konzumacija i obrada mlijeka bile široko prihvaćene u neolitiku u Europi prije nego se perzistencija laktaze pojavila ili postala česta. Stoga možemo pretpostaviti da u normalnim okolnostima perzistencija laktaze ne mora nužno biti vezana sa snažnom selekcijom u ovoj populaciji što odgovara hipotezi da su se mljekarstvo i konzumacija mlijeka pojavili prije genske adaptacije.

RANA ZEMLJORADNJA NA SJEVERNOM JADRANU

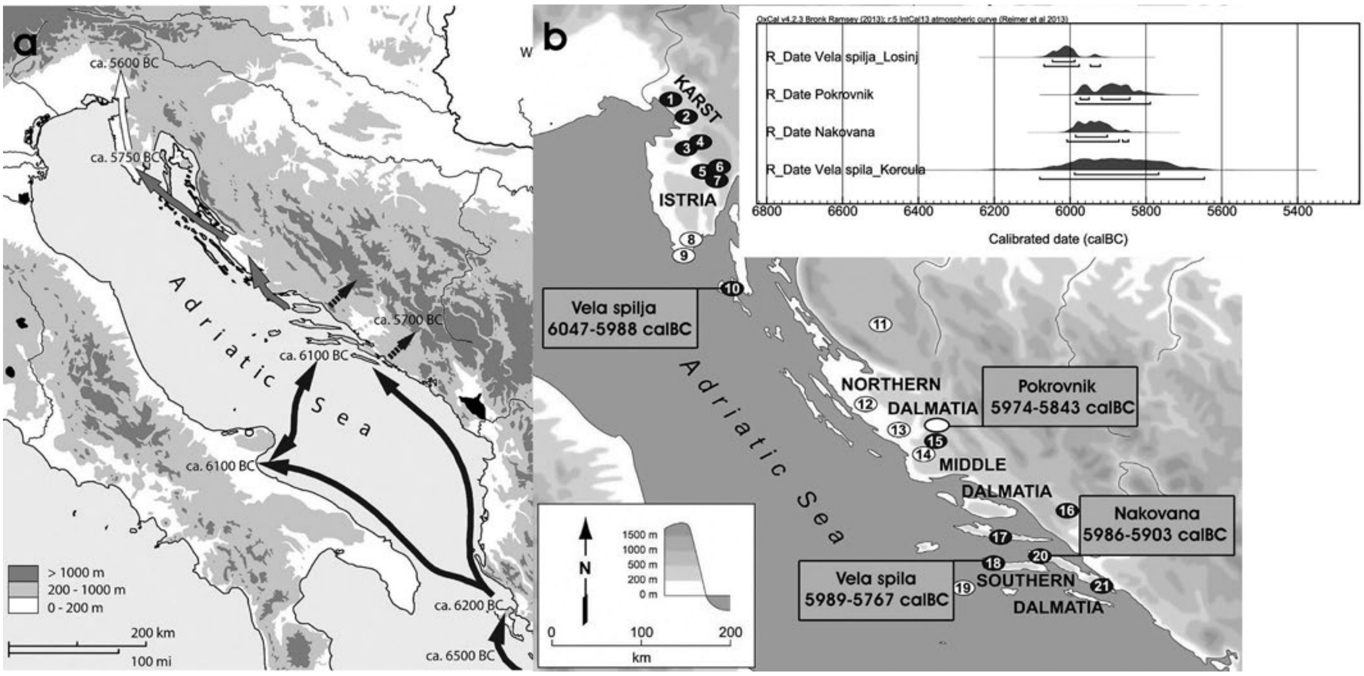
Distribucija prvih zemljoradničkih zajednica na istočnom Jadranu tradicionalno se povezuje s rasprostranjenošću impresso-cardium keramike i migracijskim modelima demičke difuzije.

Koristi se također i kao pokazatelj širenja zemljoradnje u regiji. Stašo Forenbaher i Preston Miracle[29] zagovaraju model s dvije faze prema kojem impresso keramika potječe sa sjevernih grčkih obala a širila se imigracijom s juga na sjever duž jadranske obale. U ovaj proces su bili uključeni zemljoradnici imigranti koji su poduzimali istraživačke izlete i osnivali kratkotrajne sezonske kampove u pećinama i u nalazištima na otvorenom uz obalu južne Dalmacije (inicijalna kolonizacija) nakon čega je slijedilo naseljavanje u selima koje se polako širilo prema sjevernom Jadranu u područjima plodnih tala (faza konsolidacije). Postojeći radiokarbonski datumi ne podržavaju postupni kolonizacijski model jer u osnovi nema kronološke razlike između pojave i širenja impresso keramike na južnom i sjevernom Jadranu[30] (Sl. 2).[31] Početak ranog neolitika na istočnom Jadranu se najvjerojatnije može datirati u period između 6048.–5988. kal. god. pr. Kr. na sjeveru (Vela spilja na otoku Lošinju), 5985.–5843. kal. god. pr. Kr. u

29 S. FORENBAHER, P. MIRACLE, 2005; S. FORENBAHER, P. MIRACLE, 2006.

30 S. FORENBAHER *et alii*, 2013.

31 Nedavno objavljeni ^{14}C datumi: 7134±37 BP (OxA–18118) za Velu spilju, na otoku Lošinju; 7000±100 BP (nedostupan laboratorijski kod) za Kargadur 6769±33 BP, 6612±32 (OxA–21092, OxA–21093) i Vižulu 6140±70 (HD–11733) na južnom kraju istarskog poluotoka i 6999±37 BP (OxA–17194) za Pokrovnik u Dalmaciji; 7050±37 (OxA–18120) za Spilu Nakovana na Pelješcu i 7000±120 (Z–1968) za Velu spilu (C. BONSAL *et alii*, 2013, 149, Tab. 8.1; S. FORENBAHER *et alii*, 2013, Tab. 1). Datum iz Vele spile, originalno pripisan ranoj "impresso cardium" keramici 7300±120 BP, Z–1967, je nedavno povezan s prijelaznim "mezolitičko-neolitičkim razdobljem" (S. FORENBAHER *et alii*, 2013, 597). Datumi su kalibrirani na vjerojatnost 68.2 koristeći Oxcal 4.2 program.



SL. 2. / FIG. 2.

(a) The colonisation model of Eastern Adriatic based on the hypothesised gradual spread of impressed pottery along the eastern Adriatic coast (S. FORENBAHER, P. MIRACLE, 2005, Fig. 4). (b) The available radiocarbon data sets do not confirm the gradual spread of pottery as there is no essential chronological difference in impressed pottery appearance and dispersal in Southern and Northern Adriatic (modified after S. FORENBAHER *et alii*, 2013, Fig. 1).

(a) Kolonizacijski model za istočni Jadran utemeljen na hipotetičkom postupnom širenju impresso keramike duž jadranske obale (S. FORENBAHER, P. MIRACLE, 2005, Fig. 4). (b) Dostupni radiokarbonski datumi ne potvrđuju postupno širenje keramike jer u osnovi nema kronološke razlike u pojavljivanju i raširenosti impresso keramike na južnom i sjevernom Jadranu (modificirano prema S. FORENBAHER et alii, 2013, sl. 1).

the central region (Pokrovnik in Dalmatia), and between 5986–5903 calBC (Spila Nakovana on Pelješac peninsula) and 5989–5767 (Vela spila on Korčula Island) in the South.

The available ^{14}C evidences in the Northern Adriatic show that the Istrian peninsula and Karst Plateau above Trieste Bay remained outside this range. It is postulated that the Neolithic was established here at *c.* 5600 calBC and that it was associated with the end of "*Impressed Ware and the appearance of assemblages with only undecorated pottery*" (*i.e.* Vlaška-Danilo pottery) in the Middle Neolithic.[32] The northern boundary of "Impresso Cardium" pottery through the Eastern Adriatic is positioned in southern Istria, although the pottery was found in cave sites in the coastal fringe of the Trieste Bay.[33] However, in most sites across the boundary, the earliest Neolithic is represented by Vlaška pottery.[34] These pottery assemblages resemble those from the

središnjoj regiji (Pokrovnik u Dalmaciji) te između 5986.–5903. kal. god. pr. Kr. (Spila Nakovana na poluotoku Pelješcu) i 5989.–5767. kal. god. pr. Kr. (Vela spila na otoku Korčuli) na jugu.

Raspoloživi ^{14}C datumi za sjeverni Jadran pokazuju da su istarski poluotok i krška zaravan iznad Tršćanskog zaljeva ostali izvan ovih okvira. Pretpostavlja se da je neolitik ovdje počeo oko 5600 kal. god. pr. Kr. i da je povezan s krajem "*impresso keramike i pojavom isključivo neukrašene keramike*" (odnosno keramike Vlaška-Danilo tipa) u srednjem neolitiku.[32] Sjeverna granica "impresso-cardium" keramike na istočnom Jadranu nalazi se u južnoj Istri iako se takva keramika nalazila i u pećinskim nalazištima u obalnom pojasu Tršćanskog zaljeva.[33] Ipak, u većini nalazišta izvan te granice najraniji neolitik je zastupljen keramikom vlaške kulture.[34] Ovi keramički nalazi nalikuju srednjoneolitičkim danilskim artefaktima iz Dalmacije a pretpostav-

32 S. FORENBAHER *et alii*, 2013, 599.

33 Pečina na Leskovcu, Pečina pod Muzarji, Pečina pod Steno, Pejca v Zavodu and Orehova Pejca (see T. FABEC, 2003, 108).

34 L. BARFIELD, 1972.

32 S. FORENBAHER *et alii*, 2013, 599.

33 Pečina na Leskovcu, Pečina pod Muzarji, Pečina pod Steno, Pejca v Zavodu and Orehova Pejca (vidi T. FABEC, 2003, 108).

34 L. BARFIELD, 1972.

Middle Neolithic Danilo culture in Dalmatia, and it has been hypothesised that the region was not colonised before the Middle Neolithic.[35] Nevertheless, we may assume that the Vlaška group does not represent the initial Neolithic in the region. Materialities in stratigraphicaly super-positioned layers 2a and 3a at the Edera/Stenašca rock shelter show that the first can be recognised as the Vlaška group, but the latter contained plain pottery of local and non-local manufacture, along with the bones of domestic (*i.e.* caprines, cattle and pig) and wild animals, shells of marine molluscs and lithics that includes trapezes and microburins. It was recognised as a Late Castelnovian hunter-gatherer complex and dated to 6700 ± 130 BP (5700–5515 calBC).[36]

Interestingly, Mesolithic sites are known in this area,[37] but not well radiocarbon dated. On the other hand, radiocarbon sequences from some sites in this region show a temporal gap between the latest Mesolithic and earliest Neolithic occupations that varied in duration and were not synchronous among the sites, although there is an evident continuity of occupation over the wider region. Various hypotheses have already been proposed to account for the temporal discontinuity, but it remains unresolved.[38]

HOW THE VLAŠKA GROUP HERDERS MANAGED OVICAPRIDS

The question of how the Neolithic Vlaška group herders managed herds has been addressed already. Most authors agree that Vlaška group herders were involved in some form of transhumant or nomadic pastoralism, with seasonal occupation of cave sites.[39] However, contradictory scenarios have been proposed based on the interpretation of kill-off curves.[40] It is worth remembering that Sebastian Payne proposed[41] – on the basis of his ethnoarchaeological research among Turkish pastoralists – a middle range theory, which links flock management strategies to

lja se da ovo područje nije bilo kolonizirano prije srednjeg neolitika.[35] Usprkos tome ipak možemo pretpostaviti da vlaška kultura ne predstavlja početak neolitika u ovoj regiji. Nalazi iz superponiranih slojeva 2a i 3a na nalazištu Edera/Stenašca pokazuju da prvi može biti pripisan vlaškoj kulturi, ali je drugi sadržavao običnu keramiku lokalne ili nelokalne proizvodnje zajedno s kostima domaćih (koze, goveda i svinje) i divljih životinja, morskim školjkama i kremenim nalazima koji uključuju trapeze i mikro-dubila. Ovaj sloj je prepoznat kao lovačko-sakupljački kompleks iz kasnog Castelnoviana i datiran u 6700 ± 130 prije sadašnjosti (5700.–5515. kal. god. pr. Kr.).[36]

Zanimljivo je da su mezolitički lokaliteti također poznati na ovom području,[37] ali su radiokarbonski podaci oskudni. S druge strane, nizovi ^{14}C datuma s drugih nalazišta u ovoj regiji pokazuju kronološki nesrazmjer između zadnjih mezolitičkih i najranijih neolitičkih naseljavanja koja su različito trajala i nisu bila istovremena, iako je primjetan kontinuitet naseljavanja u široj regiji. Različite hipoteze objašnjavaju taj vremenski diskontinuitet, ali on i dalje ostaje neriješen.[38]

ULOGA OVIKAPRIDA U STOČARSTVU VLAŠKE KULTURE

Već se pisalo o pitanju kako su stočari vlaške kulture upravljali stadima. Većina autora se slaže da su stočari vlaške grupe prakticirali neku vrstu transhumantnog ili nomadskog stočarstva sa sezonskim naseljavanjem pećinskih nalazišta.[39] Ipak, predloženi su kontradiktorni scenariji na osnovi interpretacije krivulja probiranja.[40] Važno je spomenuti da je Sebastian Payne[41] na osnovi etno-arheoloških istraživanja među turskim stočarima predložio teoriju srednjeg dometa koja povezuje strategije upravljanja stadom s krivuljama probiranja. Temelji se na pretpostavci da se optimizacija životinjskih proi-

35 P. BIAGI, M. SPATARO, 2001; P. BIAGI, 2003; S. FORENBAHER, P. MIRACLE, 2006; S. FORENBAHER, T. KAISER, 2006.

36 P. BIAGI, M. SPATARO, 2001, 35.

37 D. KOMŠO, 2006.

38 For discussions, see P. BIAGI, M. SPATARO, 2001; P. BIAGI, 2003; S. FORENBAHER, P. MIRACLE, 2006, 497-504; D. MLEKUŽ *et alii*, 2008; J. F. BERGER, J. GUILAINE, 2009; C. BONSALL *et alii*, 2013.

39 D. MLEKUŽ, 2005; P. MIRACLE, L. PUGSLEY, 2006.

40 See P. ROWLEY-CONWY, 2013, 163-174.

41 S. PAYNE, 1973.

35 P. BIAGI, M. SPATARO, 2001; P. BIAGI, 2003; S. FORENBAHER, P. MIRACLE, 2006; S. FORENBAHER, T. KAISER, 2006.

36 P. BIAGI, M. SPATARO, 2001, 35.

37 D. KOMŠO, 2006.

38 Za raspravu vidi: P. BIAGI, M. SPATARO, 2001; P. BIAGI, 2003; S. FORENBAHER, P. MIRACLE, 2006, 497-504; D. MLEKUŽ *et alii*, 2008; J. F. BERGER, J. GUILAINE, 2009; C. BONSALL *et alii*, 2013.

39 D. MLEKUŽ, 2005; P. MIRACLE, L. PUGSLEY, 2006.

40 Vidi P. ROWLEY-CONWY, 2013, 163-174.

41 S. PAYNE, 1973.

kill-off curves. It is based on the assumption than an optimisation of animal products can be obtained by manipulating the sex and age structure of the herd. Ideal dairying and meat models differ in the age when males are culled. In the ideal dairying model, most animals younger than two months are culled in order to reduce competition for milk with people. With an optimal meat strategy, most animals are culled after one to three years, as they achieve their maximum weight.

The interpretation of kill-off curves is complicated by a strong preservation bias against neonates and young animals on the one hand and a high natural mortality of neonates and young animals on the other. But the main problem behind the use of idealised curves is the assumption that people in the past behaved optimally. Ethnographic evidence suggests that within household-based economies, animals are used for a variety of animal products. Specialised and optimised exploitation of animal products emerges from the demands of a market-based economy. Thus, a correspondence to the ideal "dairying" model would indicate specialised production geared towards exchange.[42] Two new models for detecting animal exploitation for meat and milk have been proposed recently.[43] They suggest that caprine and cattle culling profiles in the Near East and the Mediterranean show that the exploitation of cattle, sheep and goats was aimed at milk production and not only meat from the initial Neolithic onwards. While small herds of goats were exploited mainly for milk, larger sheep herds were also for meat production. However, no curve resembles ideal strategies based on either meat or milk. Vlaška group bone assemblages are comprised predominately of sheep and goat bones (around 60% of sheep and goats and less than 10% of cattle[44]). Milk yields from small stock are generally much lower than those of cows (goats, which have up to 100% higher yields than sheep, typically produce around 125kg of milk per lactation); however, they have a very high rate of increase (up to ten times compared to cattle). This makes them especially suitable for the accumulation of large herds.[45]

Kill-off curves from the North Adriatic region[46] were interpreted as a result of the management of

42 P. HALSTEAD, 1996, 25.

43 J.-D. VIGNE, M. HELMER, 2007; J.-D. VIGNE, 2008.

44 See D. MLEKUŽ, 2005.

45 See T. INGOLD, 1980; G. DAHL, A. HJORT, 1976; D. MLEKUŽ, 2005.

46 P. MIRACLE, S. FORENBAHER, 2005; P. MIRACLE, L. PUGSLEY, 2006, 319-335, Fig. 7.27.

zvoda može postići manipulacijom spolne i dobne strukture stada. Idealni mljekarski i mesni modeli se razlikuju prema dobi kad se mužjaci izdvajaju iz stada. U idealnom mljekarskom modelu, većina životinja mlađih od dva mjeseca se izdvaja iz stada da bi se smanjilo natjecanje za mlijeko s ljudima. U optimalnoj mesnoj strategiji, većina životinja se izdvaja nakon jedne do tri godine, kad postignu maksimalnu težinu.

Interpretacija krivulja probiranja je otežana zbog loše očuvanosti kostiju i visoke stope smrtnosti mladunčadi i mladih životinja. Glavni problem upotrebe idealiziranih krivulja je pretpostavka da su se ljudi u prošlosti ponašali na optimalan način. Etnografski dokazi pokazuju da su životinje korištene za niz životinjskih proizvoda u privredama koje su se temeljile na domaćinstvima. Specijalizirana i optimizirana eksploatacija životinjskih proizvoda pojavljuje se kao odgovor na zahtjeve tržišno utemeljene privrede. Na ovaj način podudarnost s idealnim "mljekarskim" modelom bi ukazivala na specijaliziranu produkciju usmjerenu prema razmjeni.[42] U zadnje su vrijeme predložena dva nova modela za prepoznavanje eksploatacije životinja za meso i mlijeko.[43] Prema ovim modelima vrijeme probiranja stoke na Bliskom istoku i Mediteranu pokazuje da je eksploatacija goveda, ovaca i koza bila usmjerena na proizvodnju mlijeka a ne samo mesa od početka neolitika nadalje. Dok su mala stada koza korištena uglavnom za mlijeko, veća stada ovaca su se koristila i za mesnu produkciju. Nijedna krivulja ne nalikuje idealnim strategijama na osnovi mesa ili mlijeka. Nalazi kostiju iz vlaške kulture uglavnom se odnose na kosti ovaca i koza (oko 60% ovaca i koza te manje od 10% goveda[44]). Prinosi mlijeka od ovaca i koza su generalno puno niži od prinosa mlijeka krava (koze, koje daju 100% više mlijeka od ovaca, proizvode oko 125 kg mlijeka tijekom laktacije), ali imaju visoku stopu povećanja broja (do deset puta u usporedbi s govedima). Zbog toga su posebno prikladne za akumulaciju velikih stada.[45]

Krivulje probiranja za sjevernojadranski prostor[46] su protumačene kao rezultat upravljanja stadima usmjerenog ubiranju mliječnih proizvoda.

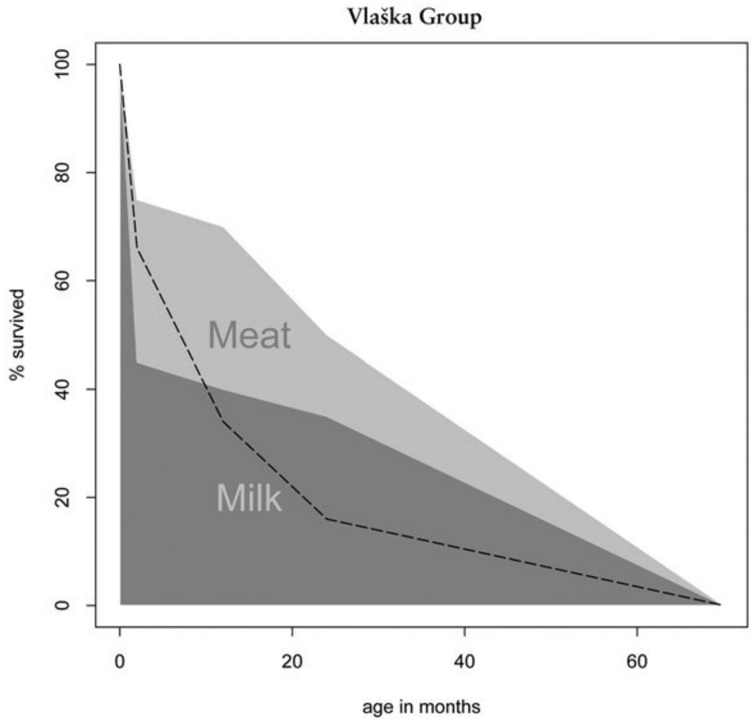
42 P. HALSTEAD, 1996, 25.

43 J.-D. VIGNE, M. HELMER, 2007; J.-D. VIGNE, 2008.

44 Vidi D. MLEKUŽ, 2005.

45 Vidi T. INGOLD, 1980; G. DAHL, A. HJORT, 1976; D. MLEKUŽ, 2005.

46 P. MIRACLE, S. FORENBAHER, 2005; P. MIRACLE, L. PUGSLEY, 2006, 319-335, Fig. 7.27.



SL. 3. / FIG. 3.

Combined kill-off curve from Caput Adriae Vlaška assemblages (Grotta dell'Edera/Stenašca, Grotta degli Zingari/Ciganska jama, Grotta del Mitreo/Mitrej and Grotta dei Ciclami/Orehova pejca; see D. MLEKUŽ, 2006). Sample size is 60 dentitions.

Kombinirana krivulja probiranja prema nalazima vlaške kulture s prostora Caput Adriae (Grotta dell'Edera/Stenašca, Grotta degli Zingari/Ciganska jama, Grotta del Mitreo/Mitrej and Grotta dei Ciclami/Orehova pejca; vidi D. MLEKUŽ, 2006). Uzorak od 60 zubala.

herds aimed at harvesting dairying products. Dimitrij Mlekuž, on the contrary, suggested that kill-off curves demonstrate a relatively simple, non-optimised economy aimed primarily at the domestic consumption of meat, not strategies aimed at maximising dairy products (Fig. 3).[47] However, this does not exclude small-scale dairying of sheep and goats. Since goats are more effective milk producers than sheep,[48] one would assume that goats were milked.[49] Goats are present after the appearance of small stock in Caput Adriae. However, their proportion compared to sheep is relatively low, around 20%, rendering their role in small-scale dairying invisible in the crude resolution of survivorship curves.

Nasuprot tome, D. Mlekuž[47] smatra da krivulje probiranja pokazuju relativno jednostavnu, neprilagođenu privredu usmjerenu prvenstveno na kućnu konzumaciju mesa, a ne strategije za maksimalnu produkciju mliječnih proizvoda (Sl. 3). Ipak ovo ne isključuje ograničeno korištenje mlijeka ovaca i koza. Pošto koze daju više mlijeka od ovaca,[48] za pretpostaviti je da su se koze muzle.[49] Koze su zastupljene nakon pojave stoke sitnog zuba u prostoru *Caput Adriae*. Ipak njihov udio u usporedbi s ovcama je relativno mali, oko 20%, čime se njihova uloga u ograničenoj proizvodnji mlijeka čini zanemarivom na krivuljama probiranja.

47 D. MLEKUŽ, 2005; D. MLEKUŽ, 2006.
48 G. DAHL, A. HJORT, 1976, 210.
49 P. ROWLEY-CONWY, 2000.

47 D. MLEKUŽ, 2005; D. MLEKUŽ, 2006.
48 G. DAHL, A. HJORT, 1976, 210.
49 P. ROWLEY-CONWY, 2000.

MOLECULAR AND ISOTOPE MARKERS OF DAIRYING IN NEOLITHIC VESSELS IN NORTHERN ADRIATIC

Biomolecular analyses of dairy fats in Neolithic pottery suggest that milking, milk consumption and processing were widely adopted in the Neolithic in Europe. Pastoralism was adopted before lactase persistence arose or became frequent.

It is well known that organic components from the foodstuffs are absorbed into the pores of unglazed ceramics without leaving any visible traces on the pot surface. The absorbed residues are protected by the clay matrix and preserved over many millennia. They are potentially present in most pottery that have been used for processing food (cooking and storing vessels), and heating seems to help the penetration of residues into the clay fabric. Animal fats are the most common residue identified in prehistoric vessels, characterised by high abundances of fatty acids, a group of lipids.

Within a grazing food web (chain) the energy and nutrients move from plants to the herbivores consuming them, and to the humans, who consume the flesh or milk of those animals. During the complex process of plant photosynthesis two biochemical reactions, the carbon fixation and fractionation determine the main plant photosynthetic pathways. The C_3 pathway or cycle is marked by the first organic carbon compound that contains a molecule with three carbon atoms. In C_4 pathway it has four carbon atoms. All the plants (vegetables, fruits, wheat and grasses) in temperate ecosystems use the C_3 cycle. Plants in tropics environments (millet, maize, sugar cane and savanna grasses), adapted to hot and arid environments, use the C_4 photosynthetic cycle. They differ in the levels of stable isotopic fractionation while assimilate atmospheric CO_2 into tissues. Plants selectively incorporate carbon into tissues taking up proportionally less ^{12}C and ^{13}C than is available in their carbon reservoir in the atmosphere. In the process of conversion of atmospheric CO_2 into organic compounds (carbohydrates, lipids and fatty acids, amino acids, and fats and oils) plants prefer to take in ^{12}C over ^{13}C and thus create different ratio of stable isotopes values ($\delta^{13}C$) than the atmosphere has. The C_3 plants show higher isotopic fractionation and $\delta^{13}C$ values range from -34 to -22‰. C_4 plants have lower isotopic fractionation and thus $\delta^{13}C$ values range within -16 and -9‰.

Because carbon isotopic fractionation between the tissues of the consumer and its diet is very small,

MOLEKULARNI I IZOTOPSKI MARKERI MLJEKARSTVA NA NEOLITIČKIM POSUDAMA SA SJEVERNOG JADRANA

Biomolekularna analiza mliječnih masti na neolitičkoj keramici ukazuje da su mužnja, konzumacija i obrada mlijeka bile široko prihvaćene u neolitiku u Europi. Stočarstvo je prihvaćeno prije nego se pojavila perzistencija laktaze ili prije nego je postala česta.

Poznato je da se organske komponente namirnica apsorbiraju u porama neglazirane keramike bez ostavljanja bilo kakvih tragova na površini posude. Apsorbirani ostaci hrane su zaštićeni glinenom matricom i sačuvani tisućljećima. Mogu biti sačuvani na većini keramike koja je korištena za pripremu hrane (posude za kuhanje i spremanje hrane). Čini se da zagrijavanje potpomaže prodiranje ostataka hrane u strukturu posude. Životinjske masti su najčešći ostaci nađeni na prapovijesnim posudama s karakterističnim visokim udjelom masnih kiselina, grupe lipida.

U biljnom hranidbenom lancu energija i nutrijenti prelaze iz biljaka u biljojede koji ih konzumiraju i zatim u ljude koji konzumiraju meso ili mlijeko tih životinja. Tijekom složenog procesa biljne fotosinteze dvije biokemijske reakcije, fiksacija i frakcinacija ugljika, određuju osnovne biljne fotosintetske puteve. C_3 put ili ciklus karakteriziran je prvim organskim spojem ugljika koji sadržava molekulu s tri atoma ugljika. U C_4 putu ima četiri ugljikova atoma. Sve biljke (povrće, voće, žitarice i trave) u umjerenim ekosustavima koriste C_3 ciklus. Biljke u tropskim krajevima (proso, kukuruz, šećerna trska i savanske trave) koje su prilagođene vrućem i suhom okolišu koriste C_4 fotosintetski ciklus. Razlikuju se po stupnjevima stabilne izotopske frakcinacije dok asimiliraju CO_2 iz atmosfere u tkiva. Biljke selektivno unose ugljik u tkiva uzimajući proporcionalno manje ^{12}C i ^{13}C nego što je dostupno u zalihama ugljika u atmosferi. U procesu pretvaranja atmosferskog CO_2 u organske tvari (ugljikohidrate, lipide i masne kiseline, aminokiseline, masti i ulja) biljke će prije uzeti ^{12}C nego ^{13}C i na ovaj način će ostvariti drukčiji udio stabilnih vrijednosti izotopa ($\delta^{13}C$) negoli je prisutan u atmosferi. C_3 biljke pokazuju veću izotopsku frakcinaciju, a vrijednosti $\delta^{13}C$ variraju od -34 do -22‰. C_4 biljke imaju manju izotopsku frakcinaciju pa zato vrijednosti $\delta^{13}C$ variraju od -16 do -9‰.

Pošto je izotopska frakcinacija ugljika između tkiva konzumenta i njegovog unosa hrane vrlo mala, od 1‰ do 2‰, vrijednosti $\delta^{13}C$ životinja su direktno from 1‰ to 2‰, $\delta^{13}C$ values of animals are directly linked to those of plants consumed by the herbivores at the beginning of the trophic chain. The negative $\delta^{13}C$ values lower than -22‰ thus indicate that the food that the individual has consumed comes mainly from C_3 plants, as well as from the flesh (fats) or milk of animals that subsisted on C_3 plants only.

The main fatty acids found in plant and animal lipids are carboxylic acids with a long chain of an even number of carbon atoms ranging from 4 to 54, which is either saturated or unsaturated. Fatty acids are usually derived from triacylglycerols (TAGs). When they are not attached to other molecules, they are known as free fatty acids. Free fatty acids and TAGs are recognised as the main biochemical markers of degraded animal fats and of origin and structural alterations of organic residue in pottery.

Although fresh animal fats comprise ca. 95% TAGs, in lipid extracts of organic residues in pottery predominate the free fatty acids that range from $C_{14:0}$ to $C_{18:0}$. The most abundant are palmitic ($C_{16:0}$) and stearic ($C_{18:0}$). The TAGs are damaged by hydrolytic degradation and converted to diacylglycerols (DAGs) and monoacylglycerols (MAGs) during vessels use and burial (Fig. 4).

Fatty acids (e.g. $C_{16:0}$ and $C_{18:0}$) are not diagnostic in themselves in identifying different food commodities that were processed and stored in the vessels, but the isotopic differences in their individual $^{13}C/^{12}C$ ratios ($\delta^{13}C$ values) are. The $\delta^{13}C$ values mark different biosynthesis of fatty acids in ruminant and non-ruminant tissues and thus allow us to distinguish between different foods residuals in prehistoric vessels. The ruminant (cattle, sheep and goat) meat and dairying products can be separated from the non-ruminant (pig) meat processing. They can be reliably measured using Gas Chromatography Combustion Isotope Ratio Mass Spectrometry (GC-C-IRMS).

The modern reference fats and the archaeological fats, *i. e.* non-ruminant porcine fats, ruminant adipose and dairy fats, collected in a C_3 environment clearly show differences in $\delta^{13}C$ values of $C_{18:0}$ fatty acids. In non-ruminant fats the $\delta^{13}C_{18:0}$ value is around -24,4‰. The $\delta^{13}C_{18:0}$ value in ruminant adipose fat is around -31.7 ‰ while the $\delta^{13}C_{18:0}$ value in dairy fat is around -34.0‰. Stearic acid in milk fat has a $\delta^{13}C$ value 2.3‰ lower compared to the same fatty acid in adipose fat. In order to remove any exogenous influences, such as variability in diet, season and other environmental factors, and retain only the metabolic influences on the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids this difference is commonly ex-

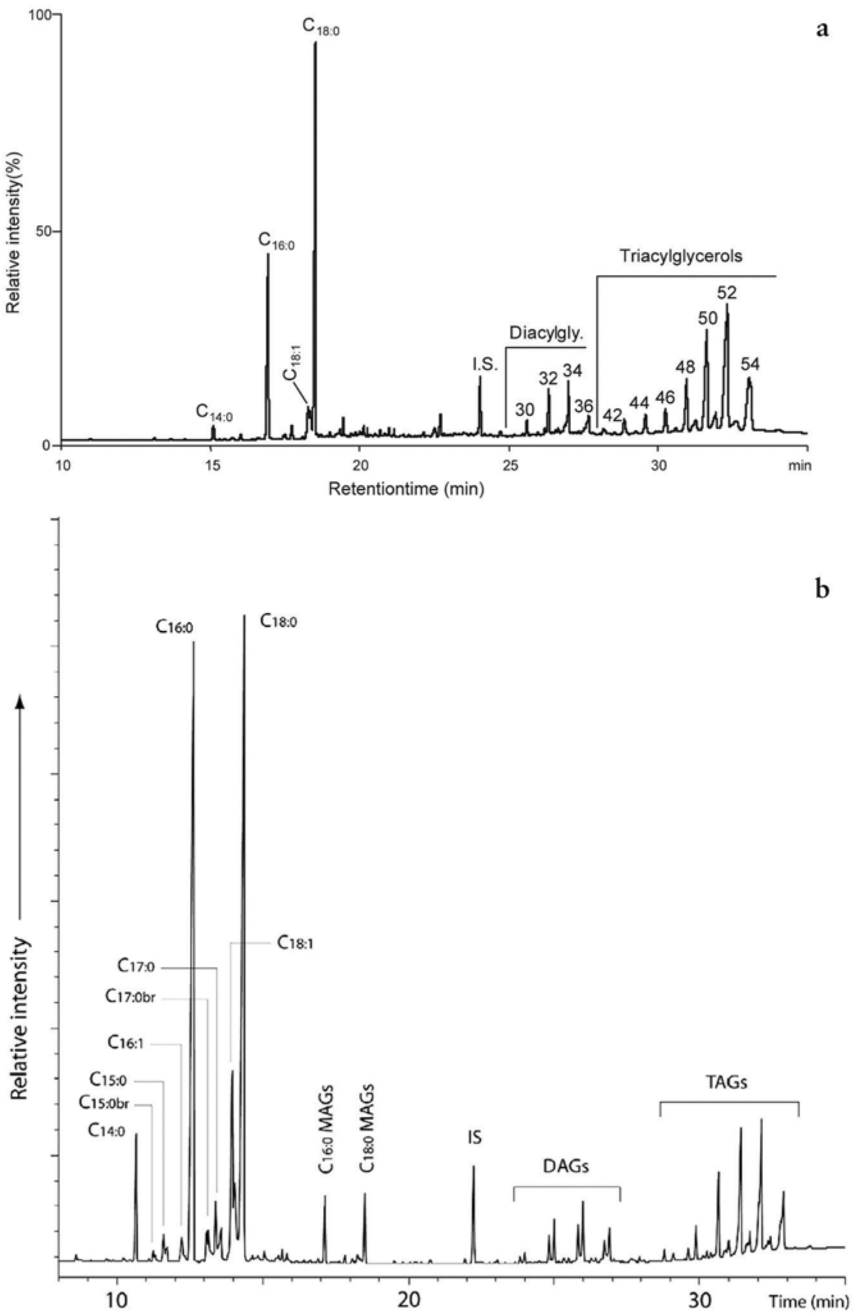
povezane s istim vrijednostima biljaka koje unose biljojedi na početku hranidbenog lanca. Negativne $\delta^{13}C$ vrijednosti niže od -22‰ na taj način pokazuju da hrana koju je pojedinac konzumirao uglavnom potječe od C_3 biljaka kao i od mesa (masti) ili mlijeka životinja koje su se hranile samo C_3 biljakama.

Osnovne masne kiseline u biljnim i životinjskim lipidima su karboksilne kiseline s dugim lancem ujednačenog broja atoma koji varira od 4 do 54 a mogu biti zasićene ili nezasićene. Masne kiseline se obično dobivaju od triglicerida. Ako nisu vezane za druge molekule, poznate su kao slobodne masne kiseline. Slobodne masne kiseline i trigliceridi su osnovni biokemijski markeri raspadnutih životinjskih masti i porijekla i strukturnih promjena organskih ostataka u keramici.

Iako svježe životinjske masti čine otprilike 95% triglicerida, masne kiseline s varijacijama od $C_{14:0}$ do $C_{18:0}$ dominiraju u lipidnim ekstraktima organskih ostataka na keramici. Najčešće su palmitinska ($C_{16:0}$) i stearinska ($C_{18:0}$) kiselina. Trigliceridi se oštećuju u hidrolitičkoj degradaciji i pretvaraju u digliceride (DAG) i monogliceride (MAG) tijekom upotrebe posude i pokapanja (Sl. 4).

Masne kiseline (npr. $C_{16:0}$ i $C_{18:0}$) same po sebi ne mogu otkriti razne vrste hrane koje su se obrađivale i spremale u posudama, ali izotopske razlike u njihovim individualnim $^{13}C/^{12}C$ omjerima ($\delta^{13}C$ vrijednosti) mogu. $\delta^{13}C$ vrijednosti označavaju različite biosinteze masnih kiselina u tkivima preživača i nepreživača i na taj način nam omogućaju razlikovanje različitih ostataka hrane na prapovijesnim posudama. Meso preživača (goveda, ovaca i koza) i mliječni proizvodi se mogu odvojiti od nepreživačkog (svinjskog) mesa. Mogu se pouzdano izmjeriti koristeći GC-C-IRMS (*Gas Chromatography Combustion Isotope Ratio Mass Spectrometry*).

Suvremene referentne masti i arheološke masti odnosno nepreživačke svinjske masti, preživačke masti iz tkiva i mliječne masti prikupljene u C_3 okolišu jasno pokazuju razlike u $\delta^{13}C$ vrijednostima $C_{18:0}$ masnih kiselina. Kod nepreživačkih masti $\delta^{13}C_{18:0}$ vrijednost je oko -24,4‰. $\delta^{13}C_{18:0}$ vrijednost u preživačkim mastima iz tkiva je oko -31.7 ‰ dok je $\delta^{13}C_{18:0}$ vrijednost u mliječnoj masti oko -34.0 ‰. Stearinska kiselina u mliječnoj masti ima $\delta^{13}C$ vrijednost 2.3‰ manju u usporedbi s istom masnom kiselinom u masti iz tkiva. Da bi se eliminirali bilo kakvi vanjski utjecaji, kao što su varijabilnosti u prehrani, godišnjem dobu i drugi ambijentalni faktori i zadržali samo metabolički utjecaji na $\delta^{13}C$ vrijednosti $C_{16:0}$ i $C_{18:0}$ masnih kiselina ova razlika se obično



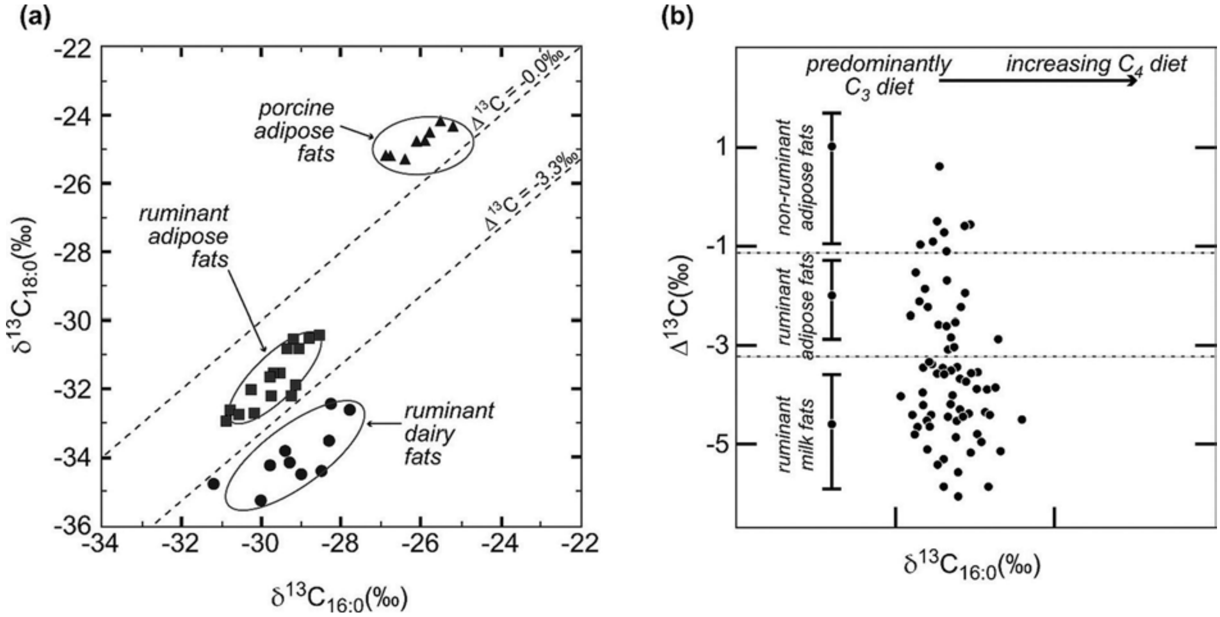
SL. 4. / FIG. 4.

Characteristic gas chromatograms of the total lipid extract obtained from Neolithic pottery: (a) Chalain and (b) Mala Triglavca (from M. REGERT, 2011, Fig. 5 and L. ŠOBERL *et alii*, 2008, Fig 1).

Karakteristični plinski kromatogrami ukupnih lipidnih ekstrakata iz neolitičke keramike; (a) Chalain i (b) Mala Triglavca (prema M. REGERT, 2011, sl. 5. i L. ŠOBERL et alii, 2008, sl 1).

pressed as $\Delta^{13}C$, where $\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$. (Fig. 5). $\Delta^{13}C$ values of the main fatty acids vary from -5.9 to +1.8 ‰. While values lower than -3,3‰ indicates ruminant dairy fats (cattle, sheep and goat milk and milk products production and consumption), values lower than -1.1‰ suggest ruminant adipose fat (cattle, sheep and goat meat processing and consumption). Values close to 0 and higher indicate non-ruminat fats (porcine meat processing and consumption).

izražava kao $\Delta^{13}C$, gdje je $\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$. (Sl. 5). $\Delta^{13}C$ vrijednosti glavnih masnih kiselina variraju od -5.9 do +1.8 ‰. Dok vrijednosti manje od -3,3‰ ukazuju na preživačke mliječne masti (proizvodnja i konzumacija kravljeg, ovčjeg i kozjeg mlijeka i mliječnih proizvoda), vrijednosti manje od -1.1‰ ukazuju na preživačke masti iz tkiva (obrada i konzumacija kravljeg, ovčjeg i kozjeg mesa). Vrijednosti bliže 0 i veće ukazuju na nepreživačke masti (obrada i konzumacija svinjskog mesa).



SL. 5. / FIG. 5.

(a) Plot of the $\delta^{13}C$ values of the major fatty acids components ($C_{16:0}$ and $C_{18:0}$) of modern reference fats (porcine adipose fats, ruminant adipose fats, ruminant dairy fats (b) Plots of the $\Delta^{13}C$ values for archaeological animal fat residues in pottery showing an emphasis on dairy products (from M. SALQUE, 2012, Fig. 7).

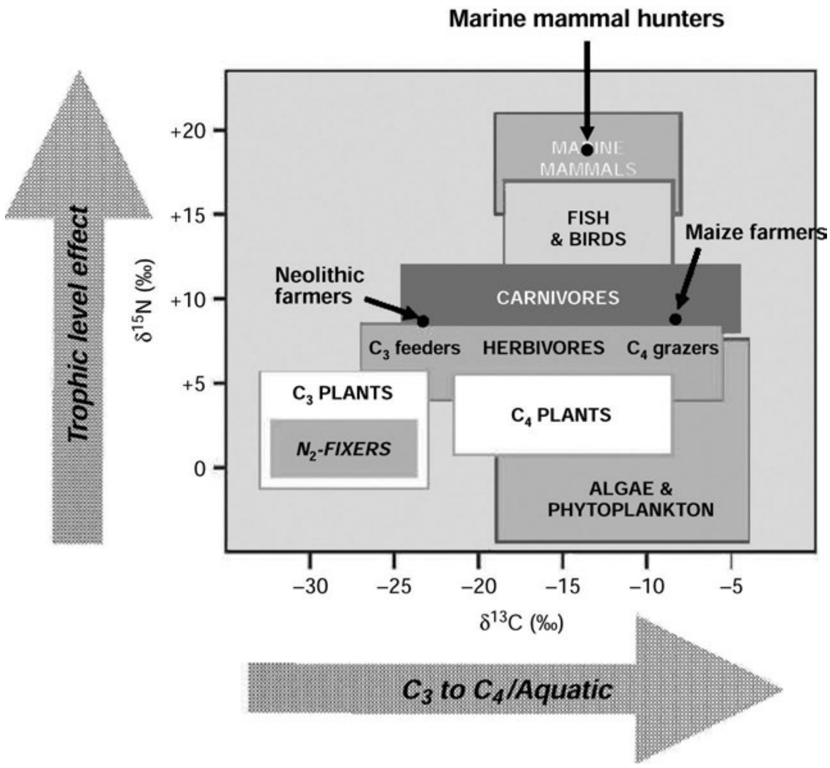
(a) Grafički prikaz $\delta^{13}C$ vrijednosti za glavne sastojke masnih kiselina ($C_{16:0}$ i $C_{18:0}$) modernih referentnih masti (svinjske masti iz tkiva, preživačke masti iz tkiva, preživačke mliječne masti (b) Grafički prikaz $\delta^{13}C$ vrijednosti za arheološke ostatke životinjskih masti na keramici s naglaskom na mliječne proizvode (iz M. SALQUE, 2012, sl. 7).

The TAGs distributions (biomarker) show similar differences when they are well-preserved in pottery. Ruminant adipose fats contain TAGs with number of carbon atoms ranging from C_{42} (for bovine) or C_{44} (for ovine) and C_{54}. The non-ruminant adipose fat (porcine) relates to a narrower distribution of TAGs that range from C_{44} to C_{54}, with very low abundances of C_{44}, C_{46}, and C_{48}. In ruminant dairy fats the TAGs distribution ranges from C_{28} to C_{54}. Additionally, cow and goat milks differed in the relative abundance of $C_{10:0}$ (capric acid) which is higher in goat than in cow milk.

The differences correlate to different ruminant and non-ruminant metabolic and digestive pathways. Although both groups of animals produce fatty acids in adipose fats by *de novo* synthesis, the carbon source is not the same. Ruminants, species with extensive foregut fermentation (e.g., cattle, goat, and sheep), incorporate carbon from acetate to biosynthesize palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids. Porcine (non-ruminant) uses carbon from both acetate and glucose to produce the same fatty acids. These differences explain why their adipose fats can be discriminated by their $\delta^{13}C$ values. The identification of fine structure of triacylglycerols (TAGs) can be done by soft ionization techniques, electrospray (ESI) and atmospheric pressure chemical ionization (APCI).

Distribucije triglicerida (biomarker) pokazuju slične razlike kad su dobro sačuvani u keramici. Preživačke masti iz tkiva sadržavaju trigliceride s brojem ugljikovih atoma koji varira od C_{42} (za goveda) ili C_{44} (za ovce) i C_{54}. Nepreživačke masti iz tkiva (svinjske) se odnose na užu distribuciju triglicerida koja varira od C_{44} do C_{54}, s vrlo niskim količinama C_{44}, C_{46} i C_{48}. U preživačkim mliječnim mastima distribucija triglicerida varira od C_{28} do C_{54}. K tomu, kravlje i kozje mlijeko su se razlikovali u relativnoj količini $C_{10:0}$ (kaprinska kiselina) koja je bolje zastupljena u kozjem nego u kravljem mlijeku.

Razlike su u vezi s različitim preživačkim i nepreživačkim metaboličkim i probavnim putevima. Iako obje grupe životinja proizvode masne kiseline u mastima iz tkiva sintezom *de novo*, izvor ugljika nije isti. Preživači, vrsta s izraženom prije-želučanom fermentacijom (npr. goveda, koze i ovce) uzimaju ugljik iz acetata da bi biosintetizirali palmitinsku ($C_{16:0}$) i stearinsku ($C_{18:0}$) kiselinu. Svinje (nepreživači) koriste ugljik iz acetata i glukoze da bi proizveli iste masne kiseline. Ove razlike objašnjavaju zašto se njihove masti iz tkiva mogu razlikovati na osnovi njihovih $\delta^{13}C$ vrijednosti. Identifikacija finih struktura triglicerida se može izvršiti tehnikama ionizacije, elektrosprejem (*ESI*) i kemijskom ionizacijom pri atmosferskom tlaku (*APCI*).

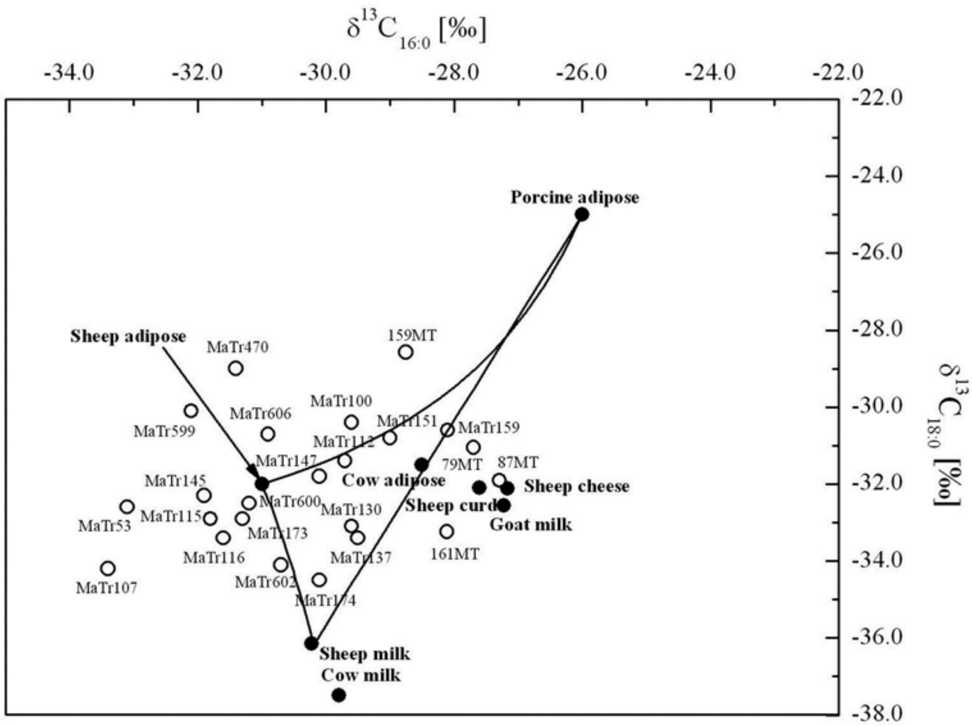


SL. 6. / FIG. 6.
Isotopic "map" of terrestrial and marine food webs (from R. EVERSHED, 2009, Fig. 14. 3).
Izotopska "karta" kopnenih i morskih prehrambenih mreža (prema R. EVERSHED, 2009, sl. 14. 3).

Parallel the C pathways the nitrogen (N) pathway determines the sequence of biochemical changes form free atmospheric N_2 to complex organic compounds in plant and animal tissues. Although there is abundant nitrogen in the atmosphere, neither the plants (except legumes) nor the animals can use it. Plants take nitrogen from the soil after the process of fixation by soil bacteria and nitrifyning bacteria. They absorbed nitrate through their roots and assimilated it into plant proteins. The $\delta^{15}N$ values ($^{15}N/^{14}N$ ratio) for the organic residues in the vessels can indicate the trophic level along the food web, as there is 2-4‰ enrichment in ^{15}N each step up the food chain. Therefore if plants have an average $\delta^{15}N$ of about 3‰, herbivores that consume those plants have $\delta^{15}N$ of about 6‰, and carnivores that consume those herbivores will have $\delta^{15}N$ of about 9‰. On the other hand the systems based on terrestrial C_3 plants can be easily distinguished from marine and fresh water systems. The isotopic composition of marine food webs tends to be more enriched in both $\delta^{15}N$ and $\delta^{13}C$ terrestrial C3 or freshwater ecosystems (Fig. 6).

Paralelno s putovima ugljika, put dušika određuje sekvencu biokemijskih promjena od slobodnog atmosferskog N_2 do kompleksnih organskih spojeva u biljkama i životinjskim tkivima. Iako ima dosta dušika u atmosferi, ni biljke (osim mahunarki) ni životinje ga ne mogu koristiti. Biljke uzimaju dušik iz tla nakon procesa fiksacije koji vrše bakterije iz tla ili dušične bakterije. One apsorbiraju nitrate kroz svoje korijene i asimiliraju ih u biljne proteine.

$\delta^{15}N$ vrijednosti (omjer $^{15}N/^{14}N$) organskih ostataka na posudama mogu ukazivati na trofični nivo u prehrambenoj mreži jer se pojavljuje 2-4‰ obogaćenje sa ^{15}N svaki idući nivo u prehrambenom lancu. Stoga, ako biljke imaju prosječni $\delta^{15}N$ od 3‰, biljojedi koji konzumiraju te biljke će imati $\delta^{15}N$ od oko 6‰, a mesojedi koji pojedu te biljojede će imati $\delta^{15}N$ od oko 9‰. S druge strane sustavi koji se temelje na kopnenim C_3 biljkama mogu se lako razlikovati od morskih i slatkovodnih sustava. Izotopski sastav morskih prehrambenih mreža se čini više obogaćenim $\delta^{15}N$ i $\delta^{13}C$ od kopnenih C_3 ili slatkovodnih ekosustava (Sl. 6).



SL. 7. / FIG. 7.

Plot of the $\delta^{13}C$ values of $C_{18:0}$ and $C_{16:0}$ fatty acids of modern reference fats (black dots) and the lipid extracts of Neolithic pottery from Mala Triglavca (white dots). The curve bounds theoretical $\delta^{13}C$ values for mixtures of different fats (from M. BUDJA *et alii*, 2013, Fig. 7).

Grafički prikaz $\delta^{13}C$ vrijednosti $C_{18:0}$ i $C_{16:0}$ masnih kiselina modernih referentnih masti (crne točke) i lipidnih ekstrakata neolitičke keramike iz Male Triglavce (bijele točke). Krivulja povezuje teoretske $\delta^{13}C$ vrijednosti za mješavine različitih masti (prema M. BUDJA et alii, 2013, sl. 7).

However, $\delta^{15}N$ relates to the bulk values for the organic residues (e.g. degraded animal and plant tissues) in the vessels. The nitrogen content of the animal adipose is very low, which made the measurement of the N isotope ratios impossible for individual compounds, i.e. animal fatty acids. The direct evidence of milk products exploitation is thus not available.[50]

In Northern Adriatic in Vlaška culture context (Mala Triglavca) it was found that 30% of sampled pottery contain lipids characteristic of dairy fats thus indicating that the processing of dairy products in pottery vessels was quite extensive. The triacylglycerols (TAGs) distributions, the indicative lipids of degraded animal fats, suggest that residues of dairy products probably derived from goat milk.

For the lipid analysis, we sampled 29 vessels from Mala Triglavca from contexts ranging from c 5460 to 4260 calBC. We studied $\delta^{15}N$ and $\delta^{13}C$ for the bulk stable isotope omposition of organic residues and for the individual fatty acids, and their

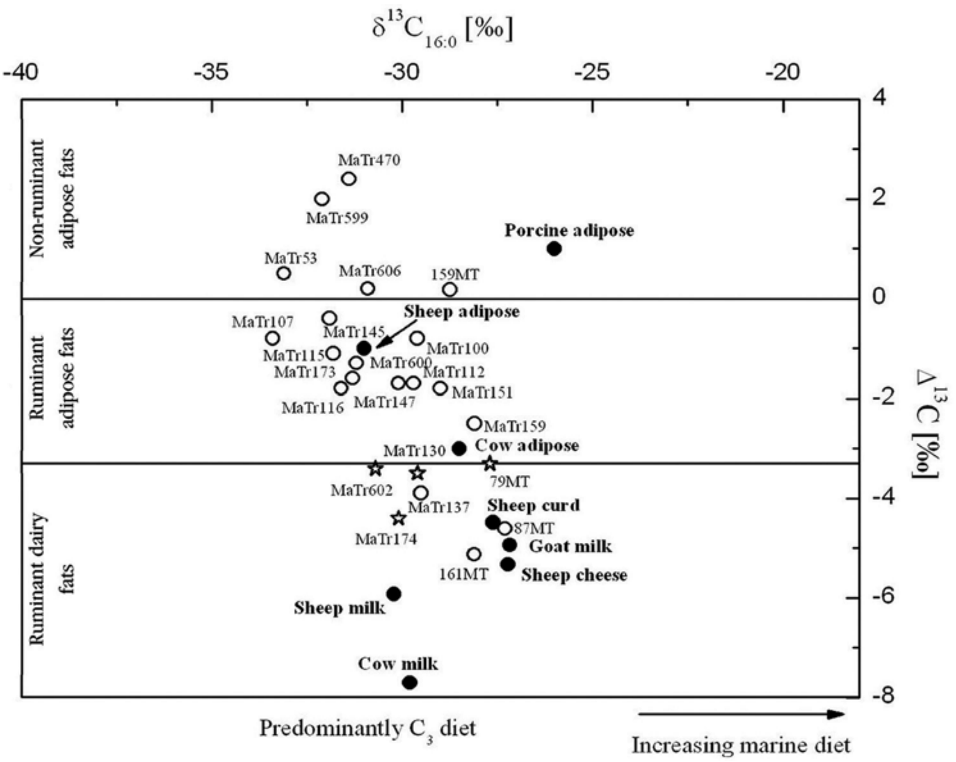
50 J. E. SPANGENBERG *et alii*, 2006; R. P. EVERSHED, 2008; R. P. EVERSHED, 2009; M. REGERT, 2011; M. SALQUE, 2012.

$\delta^{15}N$ odgovara ukupnim vrijednostima za organske ostatke (odnosno razgrađena životinjska i biljna tkiva) u posudama. Sadržaj dušika u životinjskim mastima iz tkiva je vrlo mali zbog čega je bilo nemoguće izmjeriti udio dušikovih izotopa za pojedinačne spojeve tj. životinjske masne kiseline. Izravan dokaz korištenja mliječnih proizvoda zato nije dostupan.[50]

Na sjevernom Jadranu u kontekstu vlaške kulture (Mala Triglavca) otkriveno je da 30% analizirane keramike sadrži lipidske karakteristike mliječnih masti pokazujući da je obrađivanje mliječnih proizvoda u keramičkim posudama bilo prilično intenzivno. Distribucije triglicerida, indikativni lipidi raspadnutih životinjskih masti ukazuju da se radi o ostacima mliječnih proizvoda vjerojatno od kozjeg mlijeka.

Za analizu lipida analizirali smo 29 posuda iz Male Triglavce iz konteksta u rasponu od oko 5460. do 4260. kal. god. pr. Kr. Analizirali smo $\delta^{15}N$ i $\delta^{13}C$ za ukupni sastav stabilnih izotopa organskih

50 J. E. SPANGENBERG *et alii*, 2006; R. P. EVERSHED, 2008; R. P. EVERSHED, 2009; M. REGERT, 2011; M. SALQUE, 2012.



Sl. 8. / Fig. 8.

Plot showing the difference in the $\delta^{13}C$ values of C18:0 and C16:0 fatty acids ($\Delta^{13}C$) versus $\delta^{13}C16:0$ recovered from pottery extracts from Mala Triglavca and modern reference fats (black dots). The ☆ represent fatty acids with typical degraded TAG distribution (from M. BUDJA *et alii*, 2013, Fig. 8).

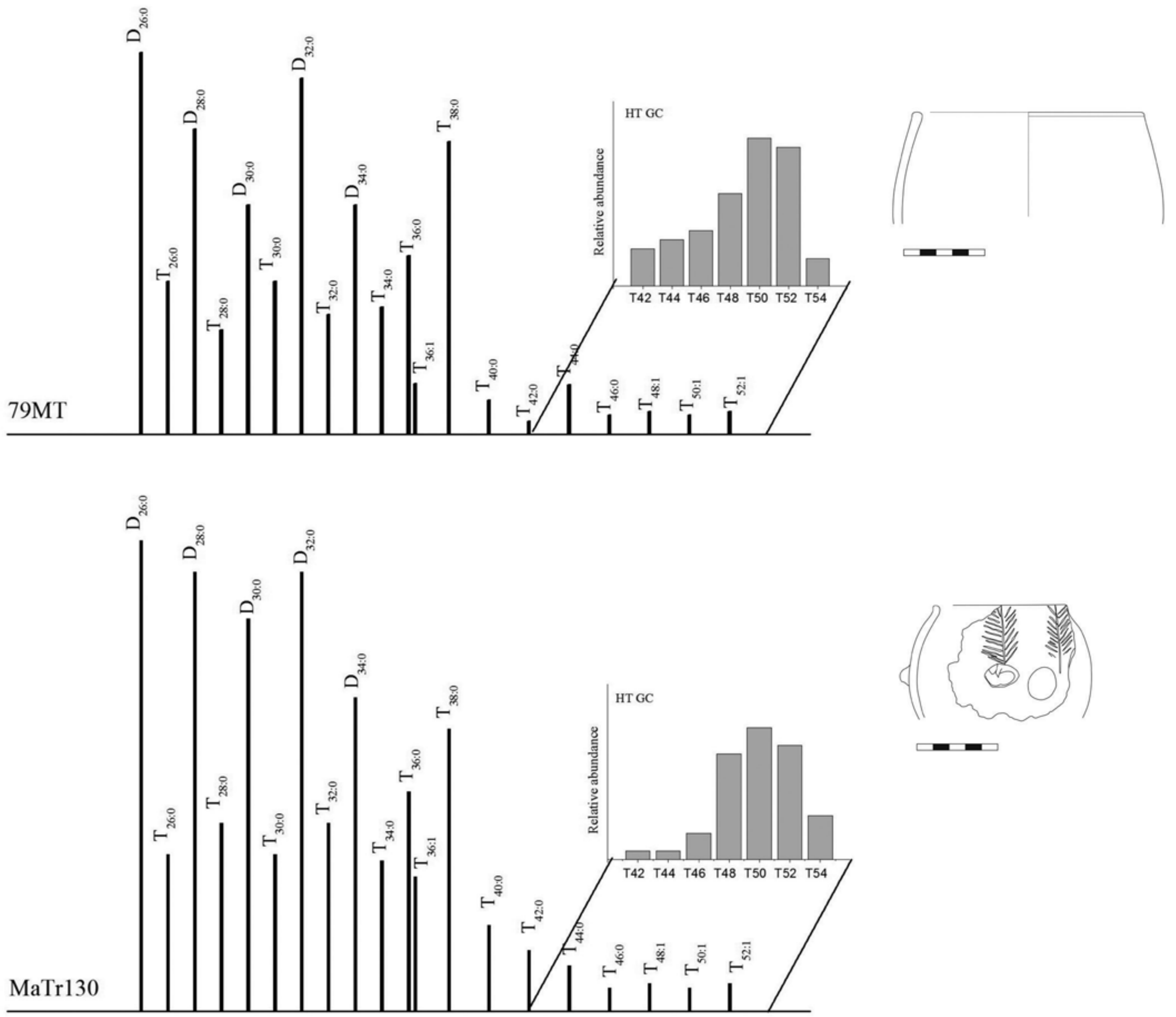
Grafički prikaz razlika između $\delta^{13}C$ vrijednosti C18:0 i C16:0 masnih kiselina ($\Delta^{13}C$) u odnosu na $\delta^{13}C16:0$ sa uzoraka s keramike iz Male Triglavce i moderne referentne masti (crne točke). ☆ predstavlja masne kiseline s tipičnom distribucijom razgrađenih triglicerida (prema M. BUDJA et alii, 2013, sl. 8).

di- and triacylglycerols (DAGs and TAGs) distributions.[51] The $\delta^{15}N$ and $\delta^{13}C$ values for the bulk stable isotope composition allow us to identify three groups of food commodities that have been processed and/or stored in the vessels. The first group with the highest $\Delta^{13}C$ ($\delta^{13}C_{18:0}$ – $\delta^{13}C_{16:0)}$ values of >2.0‰ and $\delta^{15}N$ values +8.4‰ and +10.3‰ indicate presence of molluscs and crustaceans, and freshwater fishes. The second with $\delta^{15}N$ values between +0.1 and +5.4‰ and $\Delta^{13}C$ values of around 0‰ shows that these pots were probably used to process herbivore products and/or plant materials. The third group with the $\delta^{15}N$ values that range from +5.4 to +9.7‰ and $\Delta^{13}C$ values between -0,8 and 5,1‰ indicate the presence of ruminant adipose and dairy fats. The $\delta^{13}C$ values for individual fatty acids $C_{18:0}$ and $C_{16:0}$ indicate an extensive mixing of ruminant and non-ruminant, and ruminant adipose and ruminant dairy fats in the individual vessels (Fig. 7). A more precise differentiation can be obtained by plotting $\Delta^{13}C$ against $\delta^{13}C_{16:0}$ (Fig. 8). The results show that 30% of sampled pottery contain lipids characteristic

51 M. BUDJA *et alii*, 2013, 106-112.

ostataka i za pojedinačne masne kiseline i njihove distribucije diglicerida i triglicerida.[51] $\delta^{15}N$ and $\delta^{13}C$ vrijednosti za većinu sastava stabilnih izotopa omogućuju nam da identificiramo tri grupe namirnica koje su se obrađivale i/ili spremale u posudama. Prva grupa s najvećim $\Delta^{13}C$ ($\delta^{13}C_{18:0}$ – $\delta^{13}C_{16:0)}$ vrijednostima od >2.0‰ i $\delta^{15}N$ vrijednostima +8.4‰ i +10.3‰ ukazuju na prisutnost mekušaca, rakova i slatkovodnih riba. Druga grupa s $\delta^{15}N$ vrijednostima između +0.1 i +5.4‰ i $\Delta^{13}C$ vrijednostima oko 0‰ pokazuju da su se ove posude vjerojatno koristile za obradu proizvoda od biljojeda i/ili biljnih materijala. Treća grupa s $\delta^{15}N$ vrijednostima koje variraju od +5.4 to +9.7‰ i $\Delta^{13}C$ vrijednostima između -0,8 i 5,1‰ ukazuje na prisutnost preživačkih masti iz tkiva i mliječnih masti. $\delta^{13}C$ vrijednosti za pojedinačne masne kiseline $C_{18:0}$ i $C_{16:0}$ ukazuju na rašireno miješanje preživačkih i nepreživačkih, kao i preživačkih masti iz tkiva i preživačkih mliječnih masti na pojedinačnim posudama (Sl. 7). Preciznija diferencijacija bi se mogla dobiti grafičkim prikazom $\Delta^{13}C$ i $\delta^{13}C_{16:0}$ (Sl. 8). Rezultati pokazuju da 30 %

51 M. BUDJA *et alii*, 2013, 106-112.



SL. 9. / FIG. 9.

The broad TAGs distribution (from T28 to T52) indicates the presence of dairy fat and milk products.

Šira distribucija triglicerida (od T28 do T52) pokazuje prisutnost mliječnih masti i mliječnih proizvoda.

of dairy fats indicating that the processing of dairy products in pottery vessels was quite extensive. The parallel TAG distributions that range from T44 to T54 indicate the presence of ruminant adipose or dairy fats. The narrower distribution (from T50 to T54) suggests the presence of ruminant adipose fats but the broad distribution (from T28 to T52) indicates the presence of dairy fat and milk products (Fig. 9).[52]

analizirane keramike sadrži lipide karakteristične za mliječne masti što ukazuje da je obrađivanje mliječnih proizvoda u keramičkim posudama bilo prilično izraženo. Paralelne distribucije triglicerida koje variraju od T44 do T54 ukazuju na prisutnost preživačkih masti iz tkiva ili mliječnih masti. Uža distribucija (od T50 do T54) ukazuje na zastupljenost preživačkih masti iz tkiva, a šira rasprostranjenost (od T28 do T52) ukazuje na zastupljenost mliječnih masti i mliječnih proizvoda[52] (Sl. 9).

52 For detailed information see M. BUDJA *et alii*, 2013.

52 Za detaljnije informacije vidi M. BUDJA *et alii*, 2013.

CONCLUDING REMARKS

The Mala Triglavca case study shows that the Early Neolithic economy in Caput Adriae was mixed. It consisted of milk and processed milk (low-lactose food), meat (ruminants and non-ruminants) animal products, and fresh-water fish and various plants. The Vlaška group herders managed a broader spectrum of resources than ovicaprids alone, and by fermenting milk they were able to produce a wide range of low-lactose, storable products. The initial milk processing is well embedded in the time span 5467–5227 calBC. Archaeological and biochemical data suggest that dairying was adopted in Early Neolithic in Europe before lactase persistence arose or became frequent. We may assume that under normal circumstances lactase persistence is not necessarily under very strong selection in Northern Adriatic populations and fits with the hypothesis that dairying, milk consumption and fermented milk consumption emerged before the genetic adaptation.

ZAKLJUČNA RAZMATRANJA

Istraživanje na primjeru Male Triglavce pokazuje da je privreda u ranom neolitiku na prostoru *Caput Adriae* bila miješanog tipa. Sastojala se od mlijeka i obrađenog mlijeka (hrana s malim udjelom laktoze), životinjskih mesnih proizvoda (preživači i nepreživači), slatkovodne ribe i različitih biljaka. Stočari vlaške kulture raspolagali su širim spektrom resursa, osim ovaca i koza. Fermentiranjem mlijeka znali su proizvesti široki spektar trajnih proizvoda s malim udjelom laktoze. Početna proizvodnja mlijeka se može datirati u period 5467.–5227. kal. god. pr. Kr. Arheološki i biokemijski pokazatelji ukazuju da je mljekarstvo prihvaćeno u ranom neolitiku u Europi prije nego se pojavila perzistencija laktaze ili prije nego je postala česta. Možemo pretpostaviti da u normalnim okolnostima perzistencija laktaze nije nužno bila podložna snažnoj selekciji u sjevernojadranskim populacijama što odgovara hipotezi da su se mljekarstvo, konzumacija mlijeka i konzumacija fermentiranog mlijeka pojavile prije genske prilagodbe.

Prijevod: Marija Kostić

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