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Review

An ethnobotanical perspective on traditional fermented plant foods and beverages in Eastern Europe

Renata Sõukand [a], Andrea Pieroni [b,*], Marianna Biró [c], Andrea Dénes [d], Yunus Dogan [e], Avni Hajdari [f], Raivo Kalle [a,g], Benedict Reade [h,1], Behxhet Mustafa [f], Anely Nedelcheva [i], Cassandra L. Quave [j,k], Łukasz Łuczaj [l]

[a] Estonian Literary Museum, Vanemuise 42, Tartu 51003, Estonia
[b] University of Gastronomic Sciences, Piazza Vittorio Emanuele 9, 12060 Bra/Pollenzo, Italy
[c] Institute of Ecology and Botany, MTA Centre for Ecological Research, Hungarian Academy of Science, Alkotmány u. 2-4, H-2163 Vácrátót, Hungary
[d] Natural History Department, Janus Pannonius Museum, Box 158, 7601 Pécs, Hungary
[e] Buca Faculty of Education, Dokuz Eylul University, 35150 Buca, Izmir, Turkey
[f] Institute for Biological and Environmental Research, University of Prishtina "Hasan Prishtina", Mother Teresa Str., 10000 Prishtinë, Republic of Kosovo
[g] Department of Food Science and Technology, Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences, Kreutzwaldi 62, 51014 Tartu, Estonia
[h] Nordic Food Lab, Strandgade 91, DK-1401 Copenhagen, Denmark
[i] Department of Botany, University of Sofia, Blvd. Dragan Tzankov 8, 1164 Sofia, Bulgaria
[j] Department of Dermatology, Emory University School of Medicine, 1518 Clifton Rd NE, CNR Bldg. Room 5000, Atlanta, GA 30322, USA
[k] Center for the Study of Human Health, Emory College of Arts and Sciences, 550 Asbury Circle, Candler Library 107, Atlanta, GA 30322, USA
[l] Department of Botany, Institute of Applied Biotechnology and Basic Sciences, University of Rzeszów,Werynia 502, 36-100 Kolbuszowa, Poland

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ABSTRACT

Ethnopharmacological relevance: Fermented food and beverages represent an important part of the worldwide *foodscape*, medicinal food domain and domestic strategies of health care, yet relevant traditional knowledge in Europe is poorly documented.
Methods: Review of primary ethnographic literature, archival sources and a few ad-hoc ethnobotanical field studies in seven selected Eastern European countries (Albania, Belarus, Bulgaria, Estonia, Hungary, Kosovo, and Poland) were conducted.
Results: Current or recently abandoned uses of 116 botanical taxa, belonging to 37 families in fermented food or medicinal food products were recorded. These findings demonstrate a rich bio-cultural diversity of use, and also a clear prevalence of the use of fruits of the tannin- and phenolic-rich Rosaceae species in alcoholic, lactic- and acetic acid fermented preparations. In the considered countries, fermentation still plays (or has played until recent years) a crucial role in folk cuisines and this heritage requires urgent and in-depth evaluation.
Discussion: Future studies should be aimed at further documenting and also bio-evaluating the ingredients and processes involved in the preparation of homemade fermented products, as this can be used to support local, community-based development efforts to foster food security, food sovereignty, and small-scale local food-based economies.

Contents

* Corresponding author. Tel.: +39 0172 458575; fax: +39 0172 458500.
E-mail addresses: renata@folklore.ee (R. Sõukand), a.pieroni@unisg.it (A. Pieroni), biro.marianna@okologia.mta.hu (M. Biró), denes.andrea@jpm.hu (A. Dénes), yunus.dogan@deu.edu.tr (Y. Dogan), avhajdari@hotmail.com (A. Hajdari), raivo@folklore.ee (R. Kalle), benreade@hotmail.co.uk (B. Reade), behxhetm@yahoo.com (B. Mustafa), aneli_nedelcheva@yahoo.com (A. Nedelcheva), cassy.quave@gmail.com (C.L. Quave), lukasz.luczaj@interia.pl (Ł. Łuczaj).
[1] Present address: The Scratch Series, 2B Jamaica Street, Edinburgh EH6 6HH, UK.

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1. Introduction

Foods and beverages arising from fermentation processes continue to represent an important part of the global *foodscape*. Indeed, the Food and Agriculture Organization (FAO) of the United Nations noted the significance of fermented products more than 15 years ago, highlighting their cultural and economic importance for local communities in developing countries (Battcock and Azam-Ali, 1998). We use the term "fermentation" here to refer to the transformative effect of microorganisms and their products (especially enzymes, alcohols, CO_2 and organic acids) on food as employed by humans in food preparation.

While a number of research studies and reviews have focused on indigenous fermented food in continents other than Europe (see, for example, Agbobatinkpo et al., 2011; Beuchat, 1983; Das and Deka, 2012; Garabal, 2007; LeBlanc et al., 2013; Maroyi, 2013; Masarirambi et al., 2009; McGovern et al., 2004; Singh et al., 2012; Steinkraus, 1996; Tamang and Kailasapathy, 2010; Valadez-Blanco et al., 2012; Valdez, 2012), there is still a remarkable lack of scientific documentation concerning the plant-based fermentations that have played a fundamental role in traditional European folk cuisines. The last attempt at discussing this phenomenon in Europe was completed by Maurizio (1927), almost one century ago.

Recently, some of the co-authors of this article analyzed the revival of juniper beer in Poland (Madej et al., 2014) and the resilience of wild plant-based and dairy lacto-fermented products among the Slavic Gorani of NE Albania (Quave and Pieroni, 2014). These studies have shown that fermented foods and beverages not only represent (especially up until a few decades ago) a significant part of the daily cuisine, but, most interestingly, local communities still perceive them to be a crucial part of their culture, with practices that are deeply embedded into the local environment and history. Furthermore, the availability of fermented foods contributes to food security and sovereignty, especially during the long winter periods when fresh produces are unavailable, in isolated mountainous communities of the Balkans (Quave and Pieroni, 2015).

It can be argued that the ethnobiological knowledge underpinned in the often neglected fermented food products serves as a crucial pillar for implementing food security and especially food sovereignty (Nolan and Pieroni, 2014), since they belong to local biocultural heritage, which has evolved through centuries of interactions between local societies and their environment (Nabhan, 2010). In other words, the adaptive nature of the fermentation process within a given territory, which arose from centuries of human relationships with microbial niches in the environment, suggests that the processes and products of fermentation are part of a complex socio-ecological system made of living and non-living components and of their interactions (Scott and Sullivan, 2008). In this sense, they ultimately contribute to local population identities and their gastronomic "sense of place" as well (Evans et al., 2015; Redzepi, 2010).

On the other hand, fermented foods and beverages, and especially the lacto-fermented ones, have been the focus of many bioscientific studies over the past decades. Importantly, these studies have pointed out the probiotic potential of fermented products and, in general, their remarkable role in human health and preventative medicine (Aggarwal et al., 2013; Arora et al., 2013; Borresen et al., 2012; Chorawala et al., 2011; Feyisetan et al., 2012; Franz et al., 2014; Khan, 2014; Khani et al., 2012; Lan et al., 2013; Marsh et al., 2014; Satish Kumar et al., 2013; Selhub et al., 2014; Singh and Bunger, 2014; Singh and Pracheta, 2012).

The purpose of this survey was to document traditional plant-based foods and beverages still in use or used until the recent past in seven Eastern European countries (Albania, Belarus, Bulgaria, Estonia, Hungary, Kosovo, and Poland), upon which further microbiological, nutritional, and pharmacological studies could be developed to assess their rational use. This could be useful for rural development experts, who foster projects aimed at sustaining local, endogenous, practices of domestic care. Moreover, new trajectories in both the avant-guard and the "folk" gastronomy have embraced aspects of food fermentation, particularly in terms of interesting tastes and increased perceived healthiness. The food and beverage and nutraceutical industry and the world of the sustainable gastronomy could benefit from the revival of the kinds of foods and techniques found in this paper, also beyond the communities/areas where these traditional preparations do still exist.

2. Methods

2.1. Literature review

The published ethnobotanical literature, folkloric references and gastronomic literature based on original field investigations

were considered for the following countries: Albania (Pieroni, 2008, 2010; Pieroni et al., 2005, 2011, 2013, 2014a, 2014b; Quave and Pieroni, 2014), Belarus (Bolotnikova, 1977; Łuczaj et al., 2013; Łuczaj and Köhler, 2014), Bulgaria (Pavlov, 2001; Marinov, 2003, Markova, 2011, Nedelcheva, 2013), Estonia (Kalle and Sõukand, 2012, 2013a, 2013b; Moora, 1984, 2007; Svanberg et al., 2012), Hungary (Ambrus et al., 2003; Andrásfalvy, 1957; Balassa and Ortutay, 1980; Balázs, 1998, 2008; Balázs Kovács and Kovács, 2009; Bálint, 1977; Bödi, 1981; Börcsök, 1979; Csoma, 2012; Dénes et al., 2012; Ecsedi, 1934; Égető, 2001; Farnadi et al., 2001; Gunda, 2001; Kardos, 1943; Kisbán, 1997; Kiss, 1929; Kóczián, 2014; Lantos, 2014; Nagyváthy, 1820; Oláh, 1536; Ortutay, 1977; Paládi-Kovács, 1966, 1982; Papp et al., 2014; Schilberszky, 1899; Sinkó, 1996; Szathmáry, 1930, 1932; Ujváry, 1957; Varga, 1993, 1970; Váróczi, 2013; Vincze, 1960; Zentai, 1968; Zsupos, 1987), Kosovo (Mustafa et al., 2012a, 2012b; Sejdiu, 1984), Poland (Łuczaj, 2011; Łuczaj and Köhler, 2014; Madej et al., 2014) and in the Aegean Region of Turkey (Dogan et al., 2004; Dogan, 2012).

Some of these works are well documented with voucher specimens. For example, voucher specimens of wild food plants of Poland (Łuczaj, 2011) are stored in the herbarium of the Polish Ethnographic Atlas in Cieszyn (Poland); and specimens from Western Belarus (Łuczaj et al., 2013) in the herbarium of Institute of Botany of Warsaw University, Warsaw, Poland (WA code). Nomenclature followed The Plant List (2013) for plants and Index Fungorum (2015) for fungi. The Angiosperm Phylogeny Group III system was used for family assignments (Stevens, 2012).

2.2. Field studies

A survey on current and recently abandoned uses of fermented plants was conducted during broader ethnobotanical field studies and also via a few ad-hoc investigations conducted by the authors in the years 2011–2014 in the following countries, populations, and areas (Fig. 1): Albania (AL): Albanians and Gorani of the Gora Mountains (NE Albania) – AP and CLQ; Albanians and Macedonians of Gollobordo (NE Albania) – AP; Albanians of the Rrajcë and Mokra areas and Aromanians of the Mokra area (Eastern Albania) – AP; Bulgaria (BG): Bulgarians of Rhodopes Mountains (S Bulgaria) and Bulgarian Turks originating from the same region and living in Izmir area (Turkey) – AN and YD; Estonia (EE): Estonians of Saaremaa – RS and RK; Hungary (HU): Hungarians of Ormánság, Baranya (SW Hungary) – DA; Kosovo (KS): Albanians of the Gollak area and the Albanian Alps – AH and BM; Albanians, Turks, and diverse Slavic groups (Bosniaks, Serbs, and Gorani) of the Sharr Mountains (Kosovo) – AH, AP and CLQ; Circassians of Fushë Kosovë plain (Kosovo) – AP.

Local informants were asked to free-list the food preparations or beverages based on plants, still in use or used until the recent past (in their childhood, meaning max. 50–60 years ago), which could have undergone a fermentation process (the concept of which was given in various semantic ways, depending on the interlocutors and cultural contexts). For each of the named items, researchers documented details regarding the plants involved as main or additional ingredients, their local names, ecology, part(s) used, processes/manipulations, and the final food/beverage obtained products.

In some cases data come from a participant observation approach taken by some of the co-authors who have spent their lifetime in their native countries observing local food customs (PL: the Carpathian Foothills, SE Poland – ŁŁ; EE: Eastern and Central Estonia – RS and RK).

While the major part of these data have been recently or very recently published (Kalle and Sõukand, 2013a, 2013b; Mustafa et al., 2012a, 2012b; Nedelcheva, 2013; Pieroni et al., 2014a, 2014b, 2015; Quave and Pieroni, 2014, 2015), a small section of the collected data is still unpublished.

Taxonomic identification of the wild taxa was conducted by the authors, following standard works of the respective national or former national floras (and quoted in Pieroni et al., 2014a; Mustafa et al., 2012a; Kalle and Sõukand, 2013a; Nedelcheva, 2013). Wild plant materials were collected, when available, dried, identified by authors and deposited at following herbaria: Herbarium of the

Fig. 1. Location of the countries involved into the review and the number of plant and fungi taxa used for fermentation in every country.

Table 1
Plant and fungal taxa recorded in the researched areas as used in local fermented foods.

Families	Taxa	Countries	Status	Used parts	Processing	Preparations	Main or additive components	Past or current use
Aceraceae	*Acer platanoides* L.	BY, EE, PL	C/W	Sap, opening buds	fr, pr	Beer, beverage, soup	M	pa, cu
Adoxaceae	*Sambucus ebulus* L.	HU, AL	W	Fruits	fr	Wine, distillate	M	pa, cu
	Sambucus nigra L.	BY, HU, KS, PL	W	Fruits	fr	Wine, distillate, beverage	M	cu
	Viburnum opulus L.	PL	W	Fruits	fr	Wine	M	cu
Amaranthaceae	*Atriplex* spp.	BG	W	Leaves	fr	Pickle	A	pa
	Beta vulgaris L.	BY, BG, EE, HU, PL	C	Roots	fr	Bread, distillate, pickle, soup	M/A	pa, cu
Amaryllidaceae	*Allium cepa* L.	BG, PL	C	Bulbs	fr, pr	Bread, pickle	A	cu
	Allium sativum L.	BG, EE, PL	C	Bulbs	fr	Pickle	M/A	pa, cu
	Allium schoenoprasum L.	BG	W	Bulbs, leaves	fr	Pickle	A	pa
	Allium spp.	KS	W	Bulbs	fr	Yogurt starter	A	pa
Apiaceae	*Aegopodium podagraria* L.	PL	W	Stalks, leaves	fr	Soup	M	pa
	Anethum graveolens L.	BY, BG; EE, PL	C	Aerial parts, fruits	fr	Pickle	A	pa, cu
	Apium graveolens L	BG	C	Leaves, roots	fr	Pickle	A	cu
	Carum carvi L.	BY, EE, PL	C/W	Fruits	fr	Beverage, pickle	A	cu
	Daucus carota L.	BG, EE, PL	C	Roots	fr	Pickle	M/A	pa, cu
	Heracleum sphondylium L.	BG, BY, PL	W	Stalks, leaves, roots	fr	Soup, pickle	M/A	pa
Asparagaceae	*Maianthemum bifolium* (L.) F.W. Schmidt	PL	W	Fruits	fr	Wine	M	pa
Berberidaceae	*Berberis vulgaris* L.	BG, EE, PL	C/W	Fruits, leaves	fr	Wine, pickle	M/A	pa
Betulaceae	*Betula pendula* Roth	BY, EE, HU, PL	W	Sap	fr	Beverage, wine, distillate, soup, vinegar	M	pa, cu
	Betula pubescens Ehrh.	BY, EE	W	Sap	fr	Beverage, soup	M	pa, cu
Brassicaceae	*Armoracia rusticana* P.Gaertn., B. Mey. & Scherb.	BY, BG; EE, PL	C/W	Roots, leaves	fr	Pickle	A	pa, cu
	Brassica cretica Lam.	BG	C	Leaves, inflorescences	fr	Pickle	M	cu
	Brassica nigra (L.) K.Koch	BG	C/W	Seeds	fr	Pickle	A	cu
	Brassica oleracea L.	AL, BY, BG, EE, HU, PL, KS	C	Leaves, roots	fr	Pickle	M/A	pa, cu
	Brassica rapa L.	BG, HU	C	Roots	fr	Pickle	M	pa, cu
Cannabaceae	*Humulus lupulus* L.	BY, BG, EE, HU, PL	C/W	Female inflorescences, leaves	pr	Beer, leaven	M/A	pa, cu
Compositae (Asteraceae)	*Arctium lappa* L.	PL	W	Young stalks	fr	Pickle	M	pa
	Artemisia absinthium L.	EE, HU	W	Aerial parts, leaves	fr	Wine, beer	A	pa, cu
	Cyanus segetum Hill	PL	W	Petals	fr	Beer, wine	M	pa
	Helianthus tuberosus L.	BG	C/W	Roots	fr	Pickle	M	pa
	Tanacetum vulgare L.	EE	W	Aerial parts	pr	Beer	A	pa
	Taraxacum spp.	EE, PL	W	Inflorescences	fr	Wine	M	cu
Cornaceae	*Cornus mas* L.	AL, BG, HU	C/W	Fruits	fr	Beverage, pickle, wine, vinegar	M	pa, cu
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	BG	C	Fruits (or fruit peels)	fr	Pickle	M	pa
	Cucumis melo L.	BG, HU, KS	C	Fruits (unripe, ripe, and overripe)	fr	Pickle, distillate	M	pa, cu
	Cucumis sativus L.	BY, BG, EE, HU, PL, KS	C	Fruits	fr	Pickle	M	pa, cu
	Cucurbita pepo L	BG	C	Fruits	fr	Pickle	M	cu
Cupressaceae	*Juniperus communis* L.	AL, EE, HU, PL	W	Galbula twigs	fr, pr	Beer, beverage, wine, distillate	M/A	pa, cu
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn	BY	W	Rhizomes	fr	Bread	M	pa
Ericaceae	*Empetrum nigrum* L.	EE	W	Fruits	fr	Wine	M	pa
	Ledum palustre L.	EE	W	Aerial parts	fr	Beer	A	pa
	Vaccinium myrtillus L.	AL, BY, EE, PL	W	Fruits, leaves	fr	Beverage, bread, wine, pickle	M/A	pa, cu
	Vaccinium oxycoccos L	BY, EE, PL	W	Fruits	fr	Wine, pickle	M/A	pa, cu
	Vaccinium uliginosum L.	EE, PL	W	Fruits	fr	Wine	M	pa, cu
	Vaccinium vitis-idaea L.	BG, BY	W	Fruits	fr	Wine, pickle	M	cu
	Fagopyrum esculentum Moench	HU	C	Seeds	fr	Distillate	M	pa
Fagaceae	*Fagus sylvatica* L.	AL	W	Bark	pr	Leaven	M	pa
	Quercus robur L.	BY, EE, PL	C/W	Fruits, leaves	pr	Beverage, bread, pickle	A	pa, cu
Gentianaceae	*Gentiana lutea* L.	AL	W	Roots	fr	Beverage	M	cu
Grossulariaceae	*Ribes alpinum* L.	EE	W	Fruits	fr	Wine	M	pa, cu
	Ribes nigrum L.	BY, EE, PL	C/W	Fruits, leaves, twigs	fr	Beverage, pickle, wine	M/A	pa, cu
	Ribes rubrum L.	EE, HU, PL	C	Fruits	fr	Wine	M	pa, cu

Table 1 (*continued*)

Families	Taxa	Countries	Status	Used parts	Processing	Preparations	Main or additive components	Past or current use
	Ribes spicatum Robson	PL	W	Fruits	fr	Wine	M	cu
	Ribes uva-crispa L.	EE, PL	C/W	Fruits	fr	Wine	M	cu
Lamiaceae	*Melittis melissophyllum* L.	PL	W	Leaves	fr	Distillate	A	cu
	Mentha spp.	EE	W	Aerial parts	fr	Beverage	A	pa
Lauraceae	*Laurus nobilis* L.	BG	C	Leaves	fr	Pickle	A	cu
Leguminosae	*Cicer arietinum* L.	BG	C	Seeds	fr	Leaven	M	pa
	Phaseolus vulgaris L.	BG	C	Unripe fruits, leaves	fr	Leaven, pickle	M	cu
	Pisum sativum L.	EE	C	Seeds	pr	Beverage	A	pa
	Robinia pseudoacacia L.	HU	W	Flowers	fr	Distillate	A	pa
	Vicia faba L.	EE	C	Stalks	pr	Beverage	A	pa
Linaceae	*Linum usitatissimum* L.	EE	C	Chaff	pr	Beverage	A	pa
Malvaceae	*Alcea rosea* L.	BG	W	Leaves	pr	Sarma	M	pa
	Tilia tomentosa Moench	BG	C/W	Leaves, inflorescences	pr	Sarma, leaven	M	cu
Menyanthaceae	*Menyanthes trifoliata* L.	EE	W	Aerial parts	pr	Beer	A	pa
Moraceae	*Morus alba* L.	BG, HU	C	Fruits	fr	Wine, distillate	M	pa, cu
	Morus nigra L.	BG	C	Fruits	fr	Wine	M	pa
Myricaceae	*Myrica gale* L.	EE	W	Leaves, twigs	pr	Beer	A	pa
Myrtaceae	*Pimenta dioica* (L.) Merr.	BG	C	Fruits	fr	Wine	M	cu
Piperaceae	*Piper nigrum* L.	BG, EE	C/O	fruits	fr	Pickle	A	pa, cu
Poaceae	*Avena sativa* L.	BG, BY, EE, KS	C	Grains	fr, pr	Beverage, ki(i)sel, porridge	M/A	pa, cu
	Bromus secalinus L.	EE	W	Grains	pr	Distillate	A	pa
	Hordeum distichon L.	HU	C	Grains	pr	Beer, distillate, beverage, vinegar	M	pa, cu
	Hordeum vulgare L.	BG, BY, EE, PL	C	Grains	fr, pr	Beer, distillate, beverage, leaven	M/A	pa, cu
	Panicum miliaceum L.	BG, HU	C	Grains	pr	Beer, beverage	M	pa, cu
	Secale cereale L.	BG, BY, EE, HU, PL	C	Grains	fr, pr	Beverage, bread, distillate, vinegar, other	M	pa, cu
	Zea mays L.	BG, HU	C	Grains	fr, pr	Beer, distillate, leaven, pickle	M/A	pa, cu
	Triticum spp.	BG, BY, EE, HU, PL	C	Grains	fr, pr	Beer, bread, distillate, leaven, beverage, vinegar	M/A	pa, cu
Polygonaceae	*Persicaria bistorta* (L.) Samp.	BY	W	Leaves	fr	Soup	M	pa
Polypodiaceae	*Polypodium vulgare* L.	HU	W	Roots	fr	Distillate, beverage	M	pa
Primulaceae	*Primula veris* L.	EE	W	Inflorescences	fr	Wine	M	pa, cu
Rosaceae	*Crataegus* spp.	BY, PL	C/W	Fruits	fr	Wine	M	cu
	Cydonia oblonga Mill.	BG, HU	W	Fruits	fr	Distillate, pickle	M/A	cu
	Fragaria vesca L.	BY, PL	W	Fruits	fr	Wine	M	cu
	Malus spp. (either *Malus domestica* Borkh. or *Malus sylvestris* (L.) Mill.)	AL, BY, BG, EE, HU, KS, PL	C/W	Fruits	fr	Pickle	M/A	pa, cu
	Mespilus germanica L.	BG	W	Fruits	fr	Pickle	M	pa
	Prunus × *fruticans* Weihe	HU	W	Fruits	fr	Distillate	M	pa
	Prunus armeniaca L.	HU	C	Fruit	fr	Distillate	M	pa, cu
	Prunus avium (L.) L.	BG, HU	C/W	Fruits	fr	Distillate, pickle, wine	M	pa, cu
	Prunus cerasifera Ehrh.	AL, BG, KS	C/W	Unripe and ripe fruits	fr	Cheese, distillate, pickle, wine	M/A	pa, cu
	Prunus cerasus L.	BG, BY, EE, HU, PL	C	Fruits, twigs, leaves	fr	Distillate, pickle, wine, vinegar	M/A	pa, cu
	Prunus domestica L.	AL, BG, BY, HU, KS, PL	C	Fruits, unripe fruits	fr	Distillate, pickle, vinegar	M	pa, cu
	Prunus padus L.	HU, EE, PL	W	Fruits, leaves	fr	Distillate, pickle, wine	M/A	pa, cu
	Prunus spinosa L.	AL, BG, BY, HU, KS, PL	W	Fruits	fr	Beverage, distillate, herbal liqueur, pickle, wine, vinegar	M/A	pa, cu
	Pyrus communis L.	AL, BY, HU, PL	C	Fruits	fr	Beverage, distillate, vinegar, delicacy	M	pa, cu
	Pyrus elaeagnifolia Pall.	BG	W	Fruits	fr	Pickle	M	pa
	Pyrus pyraster (L.) Burgsd.	AL, BG, BY, HU, KS, PL	W	Fruits	fr	Beverage, distillate, vinegar, delicacy, pickle	M/A	pa, cu
	Rosa spp. (mainly *Rosa canina* L.)	AL, BY, HU, KS, PL	W	Fruits	fr	Beverage, distillate, wine	M	pa, cu
	Rubus caesius L.	BG, EE	C/W	Fruits, leaves	fr	Wine, pickle	M/A	pa, cu
	Rubus frutcosus L.	HU	W	Fruits	fr	Distillate, wine	M	pa, cu
	Rubus idaeus L.	BG, EE, HU, PL	C/W	Fuits, leaves	fr	Distillate, pickle, wine	M/A	pa, cu
	Rubus saxatilis L.	EE	W	Fruits	fr	Wine	M	cu
	Rubus subgenus Rubus spp.	PL	W	Fruits	fr	Wine	M	cu
	Sorbus aucuparia L.	BY, EE, PL	W	Fruits	fr	Beverage, bread, wine	M/A	pa, cu
	Sorbus domestica L.	HU	W	Fruits	fr	Distillate	M	pa, cu
	Sorbus intermedia (Ehrh.) Pers.	EE	W	Fruits	fr	Bread	A	pa

Table 1 (*continued*)

Families	Taxa	Countries	Status	Used parts	Processing	Preparations	Main or additive components	Past or current use
	Sorbus rupicola Hedl.	EE	W	Fruits	fr	Bread	A	pa
	Sorbus torminalis (L.) Crantz	BG	W	Fruits	fr	Pickle	M	pa
Rutaceae	*Citrus limon* (L.) Osbeck	EE	O	Peels	fr	Beverage	A	pa, cu
	Citrus sinensis (L.) Osbeck	EE	O	Peels	fr	Beverage	A	pa, cu
Solanaceae	*Capsicum annuum* L	BG, HU, KS	C	Fruits	fr	Pickle	M/A	pa, cu
	Solanum lycopersicum L.	AL, BG, BY, EE, KS	C	Fruits	fr, pr	Pickle	M	pa, cu
	Solanum tuberosum L.	EE, HU, PL	C	Tubers	fr, pr	Bread, distillate, pickle, kile	M/A	pa, cu
Vitaceae	*Vitis* spp.	BG, EE, HU, PL	C/O	(Dried/unripe) fruits, twigs, leaves	fr, pr	Beverage, distillate, pickle, wine, vinegar, sarma	M/A	pa, cu

Abbreviations: Status: W – wild taxa; C/W – taxa can be found wild and cultivated, and both have been used for fermentation; C – cultivated taxa; O – taxa acquired outside the local environment. Processing: fr= fermented fresh or dried; pr=processed before fermentation in various ways (i.e. macerating, boiling, roasting, germinating, scaling, cooking); M/A: M – main component; A – additive; Use: pa= past use (used in the past by currently living generations); cu=current use. For countries see Fig. 1.

University of Gastronomic Sciences, Pollenzo (Italy); Herbarium of the University of Life Sciences, Tartu (Estonia); Herbarium of the University of Sofia (Bulgaria); Herbarium of Janus Pannonius Museum, Pécs (Hungary); Emory University Herbarium (Atlanta, USA).

Nomenclature followed also in this case The Plant List (2013) for plants and Index Fungorum (2015) for fungi and the Angiosperm Phylogeny Group III system was used for family assignments (Stevens, 2012).

3. Results and discussion

3.1. The plant biodiversity of fermentations

Table 1 reports the rich botanical diversity used to make fermented foods in the studied area. In total, 116 botanical taxa, belonging to 37 families have been documented to serve as part of the natural reservoir upon which local communities forged their food security, especially during the winter months.

The most commonly reported species in the study area were *Prunus spinosa*, *Prunus cerasus*, and *Pyrus pyraster*, with citations in six different countries; *Solanum lycopersicum*, *Cucumis sativus*, *Brassica oleracea*, *Beta vulgaris*, *Humulus lupulus*, *Prunus cerasus*, *Malus domestica*, and *Secale cereale*, with citations in five different countries; and *Rosa canina*, *Vaccinium myrtillus*, *Sambucus nigra*, *Pyrus communis*, *Anethum graveolens*, *Juniperus communis*, *Armoracia rusticana*, *Rubus idaeus*, *Betula pendula* and *Hordeum vulgare*, with citations in four different countries.

3.2. The geography of traditional plant-based fermentations

Fig. 1 shows the number of plant and fungi taxa used for fermentation in the studied countries. Most of the entries came from Bulgaria, Estonia, and Poland, demonstrating a significant predominance of plant fermentation diversity among Nordic and Slavic populations towards non-Slavic populations, such us Hungarians and Albanians.

The geographic distribution of the recorded fermented taxa is reported in Fig. 1. In all parts of the Eastern-European macro-region considered, there appears to be a broad distribution of an incredible reservoir of bio-cultural fermented food *refugia* (Barthel et al., 2013). We have found that fermentation still plays (or has played until recent years) a crucial role in the local *foodscape* and that this heritage requires urgent in-depth evaluation. However, many of the practices and artisanal skills related to these food preparations are often in the hands of the elderly generations, and less well known to younger population subsets, as is described below.

Out of all of the foods documented here, a few have particularly strong cultural value in Eastern European countries. Here we should especially mention fermented rye bread, different kinds of beers, gherkins and sauerkraut. As cereal-based staple foods such as rye and wheat sourdough breads and barley beers are the most well-known and well-documented fermented products in Eastern Europe since the times of Maurizio, we will skip their description and rather concentrate on other products lesser known outside of the region of study (Kowalski, 2000; Maurizio, 1903, 1927; Moszyński, 1929; and many other 20th century works).

Making lacto-fermented cucumbers (gherkins) is a very widespread tradition among all of the northern Slavs, all of the Baltic states (Lithuania, Latvia and Estonia) and Hungarians (Table 1). The main additives that both stabilize the fermentation process and add aroma to the end-product are garlic, horseradish, dill and leaves (e.g. *Ribes nigrum*, *Prunus cerasus* and *Quercus robur*). Sauerkraut is also still widely homemade in Eastern Europe, lacto-fermented merely with salt or with one or several additives like whole apples, slices of carrot, caraway seeds or cranberries (Table 1).

3.3. Wild vs. cultivated species and the prevalence of Rosaceae

Fig. 2 illustrates the proportion of wild and cultivated taxa used in local fermented food products in each country; while in Poland, Albania, and Kosovo wild taxa represented the large majority of the fermented species, in Bulgaria cultivated species are the core of the fermented plant cuisine.

This may be partially due to the different degree of cultural attachment to horticultural traditions, which were historically and are still predominant in the Slavic SE Europe, and minimal in non-Slavic, pastoralist, and mountain-dwelling Albanian communities.

It is notable, however, that wild plants still represent an important portion of the overall records, thus indicating the urgent need to maintain the traditional ethnobotanical and gastronomic knowledge related to the correct identification, gathering, use and processing of these ingredients.

Fig. 3 illustrates the families with the higher number of used taxa, and the proportion of plant taxa within these families recorded to be used as main components (when the main plant ingredient is/was fermented), additives (when secondary plant ingredients are/were added into the main fermented products), or both.

These findings demonstrate a clear prevalence of the tannin- and phenolic-rich Rosaceae species, whose fruits are used in

fermented foods and beverages, in alcoholic, lactic and acetic-fermented preparations.

In this context, our findings suggest that the centrality of phenolic-rich plants in the fermented domain of local cuisines echoes the crucial role played by phenolic anti-oxidants in human evolution (Benzie, 2003). Moreover, the remarkable consumption of meat and its cultural importance, which is considered at least since the last century the distinctive characteristic of all Eastern

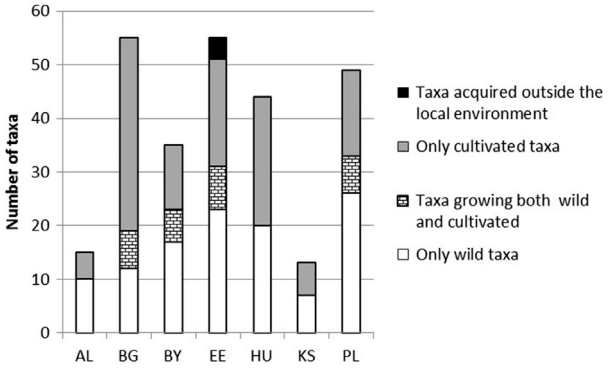

Fig. 2. Proportion of wild and cultivated taxa used in each country. AL: Albania; BG: Bulgaria; BY: Belarus; EE: Estonia; HU: Hungary; KS: Kosovo; PL: Poland.

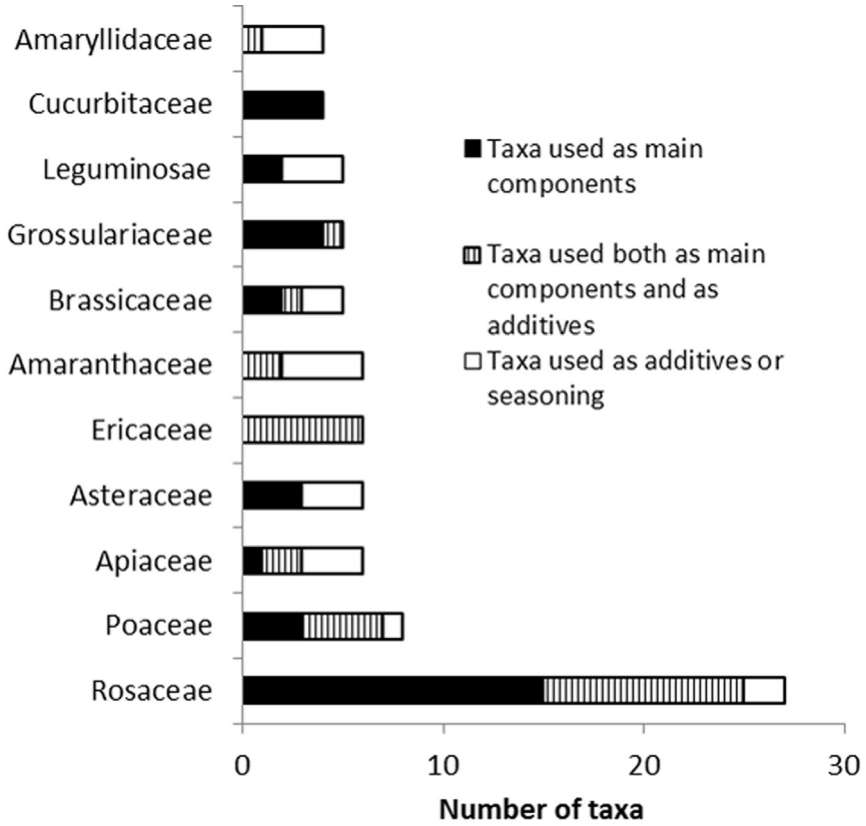

Fig. 3. Botanical families with higher number of used taxa and proportion of plant taxa used as main components, additives or both.

European diets could be nutritionally balanced by the traditional phenolic-rich fermented foods, prepared for consumption especially during the winter months, in an analogous way as it has been well described in the past for the diets of pastoralists in Western Africa (Chapman et al., 1997; Johns et al., 1999).

Fig. 4 shows the proportions of the different categories of fermented preparations that emerged from this review. These categories, according to which the recorded fermented culinary preparations were classified, correspond to the *emic* perceptions of their functions within the considered folk cuisines. Pickles and alcoholic beverages (both non-distilled beverages – beers, wines, and similar beverages – and distilled beverages, i.e. spirits) dominate the fermented plant-based folk cuisine of Eastern Europe; less relevant preparations include instead bread leaving ingredients, sour drinks, vinegars, soups, gruels, and *sarma*, i.e. fermented leaves rolled around a filling made by rice and/or minced meat and various seasoning ingredients, and very prototypical for Balkan and Near Eastern cuisines (Dogan et al., 2015).

3.4. Most uncommon (and endangered) recorded preparations

3.4.1. Gruels and sour beverages made of cereals

Fermented oat (*Avena sativa*) dishes were a popular component of the Eastern European diet but now are strongly declining.

Bexhin (or *baxhin*), a cold, thick soup made by fermented oat, is a cultural marker for the few remaining Circassian families living in the Fushë Kosovë plain of Kosovo, which represents in turn the last trace of a unique diaspora that arrived from the Caucasus in the former territory of the Ottoman Empire after their defeat (1864) in the Circassian–Russian War. The dish is prepared by roasting oat caryopsis – still locally cultivated in the area – and leaving it to ferment in a small amount of water for three days. The resulting porridge is briefly heated in order to increase the viscosity and is consumed especially by the elderly in the morning, accompanied by a glass of sirup (*sherbet*) made from sugar and water in order to compensate for the sour taste. It is considered a panacea and to be especially beneficial in the prevention of heart disease. This preparation is endangered since the know-how of *bexhin* is only retained by Circassian families, and not shared with the surrounding Roma, Albanian, and Slavic communities. Given the fact that during the last Yugoslavian Wars, the Circassian community quite entirely moved back to the Caucasus and to Turkey, this food tradition is very likely to disappear in SE Europe in the next few years, as it has already disappeared for example in Estonia and Belarus.

Different fermented dishes and drinks made of oat were widely eaten as regular meals in Estonia until the end of 19th century and sporadically until the middle of 20th century, but nowadays their popular use is limited to special groups trying to restore national food heritage (Fig. 5). For example, oat seeds were macerated in warm water, left to ferment for a few days, and then the milky water was squeezed out and the resulting sour liquor, called *kaera kiesa* or *kaerapiim*, was drunk on the side of the meal. Such a drink was also known among Votic people and called *piku pimä* (the milk for the foal), as it was also given to foals during weaning. A bit of a different beverage, called *kile*, was made of oat flour mixed with water; it was let to stay in warmth for a night. This filtered sour beverage was consumed instead of sour milk on the side of the meal. If the filtrate was boiled, it became a kind of gruel, which was also called *kile*, but also *kiisel* or *kisla*, and eaten hot with butter or fat or later, as a cold jelly. The boiling procedure took a long time at slow heat and required constant mixing; it had to meet an exact standard of sourness, otherwise it would not produce the required result. Similar gruels (also similarly named) were prepared from rye or from rye and potatoes (Moora, 2007). In Belarus, lacto-fermented gruel was called *kisiel*, but also a semi-liquid fermented dish from the oat flour was called by the same name. It was eaten with poppy or cannabis milk and is now, as in Estonia, recognized as a historical use only.

Sour foods, especially some types of cereals-based soups were widespread in Hungary but have seemingly disappeared today. Rye or wheat bran was poured into a large pot with water and fermented with an additional leavening agent. Some days later, it was filtered and the remaining material mixed with water again and kept in a warm place. It was also used as a soup or light summer beverage (Kisbán, 1997; Ortutay, 1977; Nagyváthy, 1820). The traditions of preparing and using of this beverage still exists among Hungarians living in other surrounding countries (especially in Romania).

3.4.2. Juniper beer

A fermented drink made with juniper berries as the main ingredient, usually accompanied by honey and hops, has been made in many parts of northern Poland. Similar drinks were also made in other countries around the Baltic Sea, e.g. Estonia and Finland. The use of this beverage became nearly completely obsolete in the mid-20th century but was resurrected in the Kurpie area in NE Poland and now receives a lot of media attention (Madej et al., 2014). The tradition of making this drink in northern Europe may have prehistoric origins as remnants of a similar beverage were found in some archeological sites in Denmark dating back to 1500 B.C. (McGovern et al., 2013).

3.4.3. Fermented tree saps

Birch (*Betula pendula*, *B. pubescens*) and Norway maple (*Acer platanoides*) sap has often been fermented with a small addition of grain, rye bread or dried fruits into a low-alcoholic beverage in Russia, Belarus, Ukraine, Estonia, and more rarely in Poland. Fermented birch sap was also typical in Hungary, but only from *B. pendula* (Ecsedi, 1934; Kisbán, 1997; Kiss, 1929; Papp et al., 2014; Szathmáry, 1932; Varga, 1993). Such beverages were kept in a cool dark place until the period of cutting hay or harvesting cereal in the summer. This practice has largely decreased in use, but is still living in some rural areas of Eastern and Northern Europe, as it is in Scandinavia, especially Sweden (Svanberg et al., 2012).

3.4.4. Beer-like low-alcoholic fermented drinks: taar, kvass, and kali

Historically, several low alcoholic drinks were made in Estonia. One of them, called *taar*, was made of rye and barley, rarely also oats. Grains were milled into flour and put into a tub and mixed with boiled water. Later it was poured into a specific vessel called *tõrike* which had a filter made of branches and straw at the bottom, used to prevent the thick part of the drink from coming out with the liquid part. The beverage had to turn sour for 2–3 days, and the resulting drink *taar* was taken from beneath the

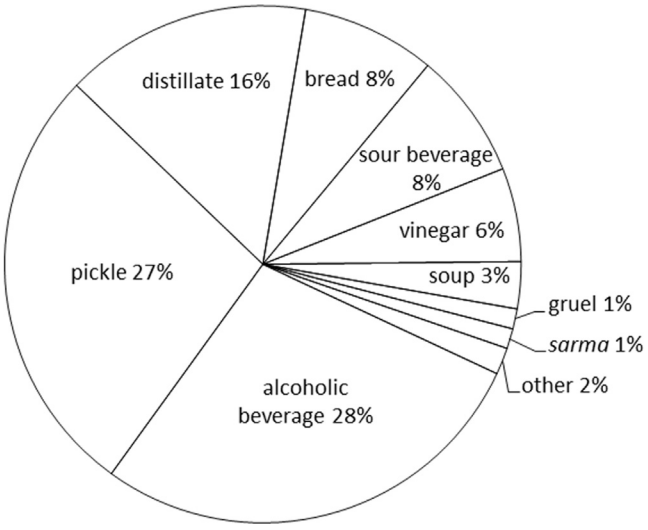

Fig. 4. Proportions of the kind of different fermented preparations recorded.

Fig. 5. Oat *kile* served at the Estonian Agriculture Museum during a conference dedicated to food culture (December 2014; photo: Renata Sõukand).

vessel. After the liquid part was consumed, more hot water was added until the resulting beverage had a taste that differed from water (Moora, 2007). To prolong the preservation of *taar* and to add specific taste, aromatic species (like *Origanum vulgare* and *Ledum palustre*) were added during the fermentation process (Kalle and Sõukand, 2013b).

In juniper-rich regions, *taar* was flavored with juniper "fruits" (galbula). Fruits were smashed with a mortar and pestle, put into a pot, covered with water and left to stay in a warm oven for 2–4 days; often the oven was repeatedly heated to retain the necessary temperature. When taken from the oven, the "fruits" were again mixed with water and left to stay for a few hours covered with a cloth; when the result “tasted good”, it was ready for consumption. However, in order to produce the beer, a source of yeast and hops were added and left to further ferment. After pouring the ready-made beer into a closed container, the leftover "fruit" draff was covered with water and fermented into *taar* (Moora, 1984). Although presently some people interviewed in Saaremaa still remember that their (grand)parents made such a drink, the authors did not succeed in documenting any modern practices. The only current day use of juniper documented was that the "fruits"-bearing branches were used as a strainer for filtering and to add a specific taste to the resulting beer.

Kvass is a popular beverage in the countries of the former Soviet Union. It is fizzy, and in homemade versions, the fermentation may be kick-started using a sourdough (mainly *Secale cereale*-based) mother culture. Nowadays, it is industrially produced, often sold pasteurized and with preservatives added, the fizz of the industrial version coming from carbonation of the pasteurized drink, rather than bottle fermentation. Unfortunately, the tradition of home-making such beverages has declined and is mainly restricted to food-conscious individuals or hobbyists. Making *kvass* was also common in parts of eastern Poland and has now all but vanished. In Estonia, historically the spent grain from beer production was used to produce *kali* (similar to *kvass*). While the technology was similar to that used to make *taar*, it was made of malted cereals and produced after the beer was already made.

3.4.5. Millet beer boza

“Beer” brewing from millet (*Panicum miliaceum*) is a very old tradition in Hungary and South-Eastern Europe (especially in Albania, Kosovo, and Macedonia). *Boza* is a slightly alcoholic (1.5%), sour drink made without any additional malt. The millet is ground, mixed with water, cooked and fermented (Balázs, 1998; Bálint, 1977; Ecsedi, 1934; Kisbán, 1997; Ortutay, 1977; Paládi-Kovács, 1966; Szathmáry, 1932). Beer brewing from millet has been recorded since the 16th century in Hungary (Oláh, 1536); the original means of preparation has disappeared, but there is another kind of preparation currently used also from millet but with some additional malted barley. In South-Eastern Europe wheat and maize flours have nowadays instead replaced millet and this tradition is mainly kept in the former Yugoslavia by (often Gorani or Slavic Muslims) artisan confectioners.

3.4.6. Lacto-fermented hogweed soup

Soup made of the lacto-fermented shoots and leaves of hogweed (*Heracleum sphondylium*) was a popular food in Poland, Lithuania and Belarus up until the 19th century and was still made in the 20th century by some individuals (Maurizio, 1927; Łuczaj, 2010, 2011; Łuczaj et al., 2013). In Belarus, some other green vegetables were fermented into a similar soup called *kisla vara* (Łuczaj et al., 2013). Unfortunately, the tradition of preparing this soup now seems to be extinct and the only sour soup made of wild green vegetables in Eastern Europe is sorrel (*Rumex acetosella* and other *R.* spp.) soup. It is important to note that in this case, the sorrel is not fermented, rather it has a natural sour taste.

3.4.7. Turshiena chorba

For Bulgarians, the liquid portion of pickles called *turshiena chorba* (туршиена чорба) is often used as the winter substitute for cold summer soups. It tastes salty, pungent, spicy and acidic. The acidity produced is the result of lactic acid fermentation in a brine solution, and the spiciness comes from the addition of hot peppers or horseradish roots. The more hot the liquid, the more intriguing: a fact which finds expression materialized in making pickles only from spicy peppers (Markova, 2011; Nedelcheva, 2013)

A comparative study on Bulgarian immigrants in Turkey (Izmir area) clearly showed that one of the best-preserved food traditions following migration is the preparation of pickles. All informants in this study described the differences between Bulgarian and Turkish pickles, defining the latter as more acidic (because of the use of citric acid), spicier and richer in components. However, they stick to well-known recipes, mainly pickled cabbage, with less vegetable additives and using vinegar for production of a moderately sour taste. Pickle liquid is perceived to be very healthy for conditions like gastritis and ulcers and is commonly used as a healthy beverage especially during the winter.

3.4.8. Salted/fermented mushrooms

Several species of fungi have been salted and lacto-fermented by Eastern Slavs, Estonians and Poles (Table 2; Fig. 6, see also Łuczaj and Köhler (2014)). This was the primary way of preserving the mushrooms for winter. The most common types of mushrooms used for this purpose were various species of milk caps (*Lactarius*). Some of them are actually toxic in a raw state (*L. rufus*, *L. torminosus*) and fermenting is one of the traditional methods for detoxifying them.

3.4.9. Green pepper fermented with grape marc törkölyös paprika

Green pepper (*Capsicum annuum* var. *longum*) inoculated with grape marc is a rare tradition of South-Hungary. Green peppers and the grape marc are layered, salted and flavored with black pepper (*Piper nigrum*), horseradish or bay in a large clay pot, usually soon after making wine. A stone is used to weigh the top of the pot and it is fermented in the cellar until December (Balázs Kovács and Kovács, 2009; Kisbán, 1997).

3.4.10. Wild apple and Cornelian cherry vinegars

The tradition of preparing home-made vinegars leaving ripe fruits of wild apple (*Malus sylvestris*) and Cornelian cherry trees (*Cornus mas*) to ferment in water for at least 30–40 days, which have been well documented more than one decade ago among the Istro-Romanians living in Croatia (Pieroni et al., 2003), is still remarkably alive in South Kosovo and NE Albania, also because the locals attribute strong health properties to these products. A small glass of homemade vinegar, with the addition of sugar, is often drunk in fact as a preventive “healthy” beverage. However, the pervasive trend of using industrial vinegars, largely available on commercial markets, may seriously endanger the transmission of the culinary knowledge concerning the home-made production of these traditional vinegars. Vinegar making from wild apple was widespread also in Hungary in the past (Gunda, 2001; Kardos, 1943; Kóczián, 2014; Ortutay, 1977; Sinkó, 1996; Varga, 1993; Zentai, 1968); Ormánság was a very important region for this, where the fruits were smashed with special machine similar to a mill wheel (Zentai, 1968) (Fig. 7). There is a renascence of preparing home-made apple vinegar in Hungary, but mainly from the cultivated varieties only.

3.4.11. Fruits and roots-based fermented beverages

A number of fruits or roots from wild (Cornelian cherries, gentian roots [*Gentiana lutea*], sloe [*Prunus spinosa*], wild apples, juniper berries [*Juniperus communis*]) and cultivated (apples, plums, damsons, cherry-plums [*Prunus cerasifera*]) plants are fermented in water by the Slavic Gorani minority living in isolated mountainous areas of NE Albania and South Kosovo to produce non-alcoholic (or low-alcohol content) fizzy, sour–sweet beverages, all of which are drunk for their refreshing quality and perceived "health" benefits (Quave and Pieroni, 2014). The traditional knowledge regarding this set of products, even partially shared with surrounding Slavic populations, is especially retained by the tiny Gorani communities and elderly women are often the only holders of this *know-how.*

In Devin area (South Bulgaria, Rhodopes Mts.), locals made a special type of fruit pickle called *vódenu* from wild apples, pears, plums, blackberries (*Rubus caesius*), raspberries (*Rubus idaeus*), lingonberries (*Vaccinium vitis-idaea*), and medlars (*Mespilus germanica*), individually or mixed. Local peoples call this mixture *hamur* or "prepared pickles in *hamur*". These pickles are prepared in a container with a tap. Fruits are added into the container, filled with water and left to ferment. After fermentation is complete, the liquid found in the bottom of the container will have a pleasantly acidic taste. This liquid is then drained and drunk, while additional water is added to the top of the container for continued fermentation. This process continues until the character of the liquid has a fruity taste. Local people call it *liuto* (люто), which means spicy, because of its unique and specific taste. This liquid was a valuable source of vitamins during the winter months, especially in the past, when fresh cultivated vegetables were not available (Markova, 2011, Nedelcheva, 2013).

4. Perspectives of plant-based fermentations in modern gastronomies, public health/nutrition, and healthy food/beverage market

Fermented foods are complex and peculiar expressions of local gastronomies; moreover, they often represent items, on which local communities often build their identity.

Human perpetuation and general use of "wild-type" starter mixtures for inoculation demonstrates an intimate traditional knowledge of fermentation kinetics and the interactions between transformative microorganisms and the core and additive ingredients. In most cases, traditional folk fermentation recipes have not been recorded with precision, and little of their microbiology is known.

The particular microbial ecology of each food product has a significant impact on shaping their gastronomic properties, since microbiota are place-specific and their use in specific culinary preparations is the result of a long co-evolution, which "expresses" the bio-cultural dimension of a given place.

Many familiar fermented foods, such as gruels, gherkins or sauerkraut can be simple to prepare (water and salt); the inclusion of seasoning or preservative plant-ingredient such as garlic, horseradish, dill, oak or blackcurrant leaves provides scope for more complex tastes and innovations.

Moreover, in gastronomy the acidic products of lactic or acetic fermentation are useful for balancing food tastes, while heterofermentative lactic acid bacteria produce carbon dioxide, which provides some fizz, and this can be a desirable aspect in a few final products.

Drinks, such as fruit beers, fermented birch saps, fruit sodas, *kvass*, *taar* and *kali* provide great gastronomic latitude as infinite variations are possible. In modern gastronomy, drinks are often used not only to hydrate and refresh, or for their alcoholic content, but rather also for the enjoyment gained from consumption of certain flavors or other characteristics, which can augment the consumer's experience of the food.

Although the functional purpose of food fermentation is often preservation based, a few of the fermented final products recorded in this work were and still are perceived by the local population as "folk nutraceuticals" (plant products ingested in order to maintain a status of health, Pieroni and Quave, 2006) and the final fermented products are often more celebrated than the original ingredients. Plant-based fermentations may offer a myriad of options to the traditional cook and the experimental chef.

Table 2
Wild fungi used for making lactofermented pickles.

Family	Taxa	Country
Boletaceae	*Boletus edulis* Bull. 1782	PL
	Leccinum spp.	BY, EE
	Suillus spp.	BY
	Xerocomus spp.	BY
Physalacriaceae	*Armillaria* spp.	PL
Russulaceae	*Lactarius deliciosus* (L.) Gray 1821	BY, EE, PL
	Lactarius deterrimus Gröger 1968	EE
	Lactarius rufus (Scop.) Fr. 1838	EE
	Lactarius salmonicolor R. Heim & Leclair 1953	PL
	Lactarius torminosus (Schaeff.) Gray 1821	EE
	Russula spp.	EE
Tricholomataceae	*Tricholoma equestre* (L.) P. Kumm. 1871	BY, PL

Fig. 6. Fermented mushrooms (Central Estonia, September 2014; photo: Renata Sõukand).

Fig. 7. Apple fermentation in Hungary: apple fruits were smashed with a special machinery similar to a mill wheel called *almatörő járgány* (apple-cracker capstan). (Picture is from the archive photo gallery of Janus Pannonius Museum, Pécs, Hungary).

Enhanced appreciation for and understanding of traditional fermentation practices could be of great benefit to those wishing to push boundaries of commercial cuisines as it provides a window into a complex nexus of interaction between plants, microbes and human culture.

Microbes are one of the most powerful tools local communities have at disposal for creating foods that are diverse, delicious, nourishing, and speak genuinely of their place in the world. Moreover, traditional fermented foods can help to improve the food security and sovereignty of local populations and should be seriously reconsidered in public/heath nutritional policies. The role of fermented foods is seen in fact nowadays as crucial in shaping modern strategies of public health/nutrition; the role of lactic fermentation products as probiotics, which are able to keep healthy gut bacteria and to prevent metabolic and cardio-vascular diseases, is in fact increasingly recognized (Lovegrove and Jackson, 2011; Quigley, 2013; Tsai et al., 2014; Sanchez et al., 2014). These findings match actually how fermented products were perceived by locals sometimes, and put the importance of evaluating the healthy benefits of these neglected food items of peasant domestic arenas into a new light.

Further studies are however urgently needed for a better understanding of the microbiology, phytochemistry, and nutraceutical potentialities of several Eastern European traditional fermented foods; these studies could also lead to the re-introduction of a few forgotten fermented products into small-scale markets.

5. Conclusions

We have presented the results of several recent ethnobotanical surveys on fermented products of Eastern Europe, with a focus on the lesser known products that are still, or were until recently, generally produced in the home. A common theme noted for production of these foods and beverages was the reliance on natural starter cultures available in the local environment, or more frequently, arising from microbes growing on the primary ingredients themselves (autochthonous “wild type” starter cultures). However, these unique sets of local knowledge are at risk as trends in the displacement of these food traditions by products of the large-scale industrialized agriculture and food industry on the market prevail, even in rural areas. This trend, combined with declines in the transmission of traditional knowledge concerning local microbial *refugia*, fermented food ingredients and fermentative processes, has resulted in the marginalization and even disappearance of many such practices today. Future studies should aim to further document rare and disappearing ethnobotanical knowledge concerning both the ingredients and processes involved in the creation of homemade fermented products as such information can have great utility in supporting local, community-based development efforts aimed at enhancing food security, food sovereignty, and small-scale local economies.

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