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Vegetable *milks* and their fermented derivative products

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Abstract

The so-called vegetable *milks* are in the spotlight thanks to their lactose-free, animal protein-free and cholesterol-free features which fit well with the current demand for healthy food products. Nevertheless, and with the exception of soya, little information is available about these types of *milks* and their derivatives. The aims of this review, therefore, are to: highlight the main nutritional benefits of the nut and cereal vegetable *milks* available on the market, fermented or not; describe the basic processing steps involved in their manufacturing process; and analyze the major problems affecting their overall quality, together with the current feasible solutions. On the basis of the information gathered, vegetable *milks* and their derivatives have excellent nutritional properties which provide them a high potential and positive market expectation. Nevertheless, optimal processing conditions for each raw material or the application of new technologies have to be researched in order to improve the quality of the products. Hence, further studies need to be developed to ensure the physical stability of the products throughout their whole shelf-life. These studies would also allow for a reduction in the amount of additives (hydrocolloids and/or emulsifiers) and thus reduce the cost of the products. In the particular case of fermented products, the use of starters which are able to both improve the quality (by synthesizing enhanced flavors and providing optimal textures) and exert health benefits for consumers (i.e. probiotics) is the main challenge to be faced in future studies.

Keywords: Nut *milk*; Cereal *milk*; Processing; Fermentation

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Abbreviations

CLSM	Confocal laser scanning microscopy
CVD	Cardiovascular diseases
DM-2	Diabetes mellitus type 2;
GI	Glycemic index
MCFA	Medium-chain fatty acids
MUFA	Mono-unsaturated fatty acids
PUFA	Poly-unsaturated fatty acids
SFA	Saturated fatty acids
UHPH	Ultra high pressure homogenization
UHT	Ultra high temperature

1 Introduction

Nowadays, there is a global awareness of nutrition-related chronic diseases. In its 2009 annual report on global health risks, the World Health Organization (WHO) determined the distribution of deaths attributable to 19 leading risk factors worldwide. More than half of these factors were nutrition-related: blood pressure due to sodium consumption, cholesterol, obesity, deficiencies of iron and zinc, among others (Stuckler & Basu, 2011). Increasingly, consumers are more aware of the relationship between nutrition and health. Indeed, newly designed foods are not only intended to satisfy hunger and provide nutrients for humans, but also to prevent nutrition-related chronic diseases and to improve well-being, both physical and mental (Burdock & Carabin, 2008; Granato, Branco, Nazzaro, Cruz, & Faria, 2010; S. Kaur & Das, 2011; Ozen, Pons, & Tur, 2012). This trend is justified if several factors are considered, such as an increase in public health awareness (a consequence of a more highly educated population), an aging population and their desire for improving the quality of their later years, an increase in healthcare costs, advances in research and technology or changes in government regulations and accountability.

The food market reflects to an ever greater degree the consumer demand for healthy food products. A clear example of this tendency can be seen in the so-called vegetable *milks* , which are mainly made of nuts and cereals and have a long history in both Eastern and Western cultures. European sales of soya *milk* and other non-dairy *milks* are increasing by over 20% per year; Spain being the EU country in which the non-dairy drinks market grew the most (Organic Monitor, 2006). Similarly, total USA retail sales of soy, almond, rice and other plant milks reached $1.3 billion in 2011 (Packaged Facts, 2012).

The best known and most popular vegetable *milk* derives from soy, although the demand for almond, rice, oat and coconut *milks* is on the increase. Wide ranges of nut and cereal vegetable *milks* are currently available on the market in a broad array of formulations: flavored, sweetened/unsweetened, low-fat and/or fortified. Excluding Asia, non-dairy *milk* alternatives (vegetable *milks*) still represent a relatively small market overall; nonetheless, the growing awareness of allergy and intolerance issues and the lactose-free, cholesterol-free and low-calorie positioning of these products are bringing about a rise in purchase levels (Stone, 2011). In fact, marketing strategies of those products focus on comparing their health benefits with those of dairy products. Furthermore, experts are starting to consider possible relations between vegetable products and the prevention of cancer, atherosclerosis or inflammatory diseases, since free radicals play a key role in those pathologies and these types of food are an excellent source of antioxidants (Scalbert & Williamson, 2000). The lactose intolerant and/or those people allergic to cow milk are prime consumers of these types of *milks*, but they are also in great demand by people without health problems, such as vegans and vegetarians.

The development and further increase in demand of such products would have an extra advantage, which could be of economic interest for many countries: the raw material they derive from (nuts and cereals) do not generally require specific soil nor climatic conditions, they are able to adapt to different climates although, of course, the productivity might change (Osca, 2007; Coniglio, 2008). For example, almond tree farming is considered to be a dry cultivation with low soil fertility, low rainfall and minimum pruning and plant protection requirements (Navarro-Muñoz, 1996; Saura, Cañellas, & Soler, 1988). Oat is a temperate crop which grows well in damp, marginal upland areas (Welch & McConnell, 2001). These facts would benefit the rapid implementation of these raw materials in non-cultivated lands around the world and maybe, this could contribute to the rural development of developing countries and allow these vegetable products to attain highly competitive prices within the world market.

Taking into account the positive trends of these products in the food market and bearing in mind that the literature contains little information about them, the aims of this work are to: highlight the main nutritional benefits of these kinds of *milks*, fermented or not; describe the basic processing steps involved in their manufacturing process; and analyze the major problems affecting the overall quality, together with the possible solutions currently available. Therefore, this review focuses on the study of nut and cereal vegetable *milks* available on the market and their fermented derivatives.

2 Types of nut and cereal vegetable *milks* and their nutritional benefits

All the commercial vegetable *milks* share common features such as being lactose-free, animal protein-free or cholesterol-free. Taking into account the raw materials and their nutritional and health properties, vegetable *milks* can be broadly classified in two large differentiated groups: nut and cereal *milks*. Both kinds of products are in the state of the art owing to the new-knowledge impact of their compounds on some current chronic diseases, such as cardiovascular diseases (CVD), type 2 Diabetes mellitus (DM-2), obesity and some cancers. These metabolic diseases are linked with our daily lifestyle, notably an unbalanced energy-rich diet, lacking in fiber and protective bioactive compounds, such as micronutrients and phytochemicals (Fardet, 2010). All these limited nutrients commented on above are readily available in both cereals and nuts.

Apart from nuts and cereals, other raw materials have been used industrially, such as tubers (e.g. tigernuts) and plants (e.g. hemp, sunflower...). However, these milky based products are only well accepted in specific countries. Despite its local commerce, tigernut *milks*has also been explained in detail in this review due to its interesting composition and health properties.

2.1 Cereal grains and their *milks*

Cereals are known as a good source of the necessary daily energy, vitamins, several minerals, dietary fiber and phytochemicals, including phenolic compounds, carotenoides, vitamin E, lignans, inulin, starch, sterols and phytates (Okarter & Liu, 2010; J. L. Ward et al., 2008). The chemical composition of those cereals whose vegetable *milk* has been commercialized is summarized in Table 1. With respect to the supply of vitamins, cereals are considered an important source of group B vitamins, especially thiamin, riboflavin, folates and niacin (McKevith, 2004). Dietary fiber is present in large quantities and this is rich in fructo-oligosaccharides, which are reportedly effective at stimulating the growth of *Bifidobacteria* and *Lactobacilli* in the human intestine (K. D. Kaur, Jha, Sabikhi, & Singh, 2011). Besides this prebiotic effect, their phenolic compounds have also been reported to possess gastroprotective properties, in addition to their antioxidant, cholesterol-lowering, anti-atherogenic, anti-carcinogenic and anti-inflammatory effects (C. Chen et al., 2004; Dykes & Rooney, 2006; Prior & Gu, 2005). Indeed, epidemiological studies have shown an association between increased wholegrain consumption and reduced risks of various types of chronic diseases, such as CVD, obesity, DM-2 and some cancers (Chan, Wang, & Holly, 2007; de Munter, Hu, Spiegelman, Franz, & van Dam, 2007; Esmaillzadeh, Mirmiran, & Azizi, 2005; Larsson, Giovannucci, Bergkvist, & Wolk, 2005; Mellen, Walsh, & Herrington, 2008; Murtaugh, Jacobs, Jacob, Steffen, & Marquart, 2003; Schatzkin, Park, Leitzmann, Hollenbeck, & Cross, 2008; van de Vijver, van den Bosch, van den Brandt, & Goldbohm, 2009). More specific properties and health benefits of each cereal grain whose vegetable *milk* has been commercialized are summarized in Table 4.

In order to gain the greatest benefit from the health properties of cereals, several aspects have to be considered. For instance, it is important to use and consume whole grain and not the refined, since most of the health components are located in the bran and germ. So, the use of the whole grain is highly recommended when producing the cereal *milks*. Another point to consider is the anti-nutrient content in some cereals, primarily phytic acid (mineral chelator) or saponins (toxic in high amounts and bitter tasting), although their presence can be reduced and/or eliminated by pre-treatment processes such as grinding, soaking, heat treatments, fermentations and germinations (Brady, Ho, Rosen, Sang, & Karwe, 2007; Sharma & Kapoor, 1996; Zhu et al., 2002). Despite the anti-nutritional components, so beneficial are whole-grain cereal's properties that important food authorities, such as the U.S. Department of Agriculture (USDA), have strongly recommended 6-11 servings of grain products daily (Dewanto, Wu, & Liu, 2002).

2.2 Nuts and nut milks

Due to their composition, nuts and nut-based products have recently attracted a great deal of attention from food, nutrition and health specialists. Table 1 shows the chemical composition of those nuts whose vegetable *milks* have been commercially produced. Nuts are rich in mono- (MUFA) and polyunsaturated fatty acids (PUFA), vegetable proteins, dietary fiber, phytosterols, polyphenols, vitamins and minerals (Phillips, Ruggio, & Ashraf-Khorassani, 2005; Segura, Javierre, Lizarraga, & Ros, 2006). Most of those compounds have antioxidant properties and are proven to provide a beneficial effect on plasma lipid profile, low-density lipoprotein (LDL) oxidation and inflammatory processes, among others (Carlson, Eisenmann, Norman, Ortiz, & Young, 2011; Egert, Kratz, Kannenberg, Fobker, & Wahrburg, 2011; Gillingham, Harris-Janz, & Jones, 2011; Jones et al., 2011; Liu, 2012; Myers & Allen, 2012; H. A. Ward et al., 2012; Whent et al., 2012). Additionally, Vinson and Cai (2012) analyzed the antioxidant efficacy in different nuts, obtaining the following order of importance: walnut > cashew > hazelnut ≈ almond. Epidemiological studies have linked frequent nut consumption to a reduced risk of CVC, DM-2 or death by all-cause mortality (Kelly & Sabate, 2006). Moreover, Li et al. (2009) observed that an increase in nut consumption was significantly associated with a more favorable plasma lipid profile, including lower LDL cholesterol, total cholesterol and apolipoprotein B-100 concentrations; but they did not observe significant associations with non-high-density lipoprotein (HDL) cholesterol or inflammatory markers. Furthermore, nuts have a high K/Na ratio, which contributes to maintain well-balanced electrolytes in the human body, and, in addition to the prebiotic effect of their dietary fiber commented on above, the carbohydrates from nuts are complex (low Glycemic Index (GI)), which help to maintain blood sugar at healthy levels.

In spite of the fact that around 50% of a nut is made up of lipids, regular nut consumption within a balanced diet has been shown to improve humans' lipid profile, increase endothelial function and reduce inflammation, without causing weight gain (C.-Y. Chen, Lapsley, & Blumberg, 2006; R. D. Mattes, Kris-Etherton, & Foster, 2008; Salas-Salvado, Casas-Agustench, Murphy, Lopez-Uriarte, & Bullo, 2008; Zambón et al., 2000). Thus, in addition to providing both nutrients and bioactive antioxidants, nut milks may be a useful dietary tool for reducing risk factors that cause diseases with a major mortality rate in developed countries, such as metabolic syndrome, DM-2 or CVD. Indeed, the U.S. Food and Drug Administration approved a health claim between nuts and heart disease, suggesting that 42 g per day of most nuts as part of a low saturated-fat and cholesterol diet may reduce the risk of heart disease (FDA. U.S. Food and Drug Administration, 2003). The European Food Safety Authority (EFSA) also published a scientific opinion on the substantiation of health claims related to nuts and essential fatty acids (omega-

Table 1: Composition of raw materials commercially used for producing vegetable *milks*. Average values shown are expressed per 100 g of edible part. Nutrient Recommended Daily Allowances corresponding to a healthy adult with standard physical activity and lifestyle are also included

RAW MATERIAL	**NUTS**				**CEREALS**												
Name	**Almond**^{A}	**Chestnut**^{A}	**Hazelnut**^{B}	**Walnut**^{B}	**Amaranth**^{B}	**Barley**^{B}	**Corn**^{B}	**Kamut**^{B}	**Millet**^{B}	**Oat**^{A}	**Quinoa**^{A}	**Rice**^{A} **(brown)**	**Sesame**^{D}	**Spelt**^{B}	**Coconut**^{B}	**Tigernut**^{A}	**RDA**^{X}
Energy KJ	2453	939	2629	2738	1554	1346	1528	1411	1583	1670	1276	1607	2660	1415	1482	1706	8374
(KCal)	-589	-225	-628	-654	-371	-352	-365	-337	-378	-401	-306	-386	-644	-338	-354	-409	-2000
Lipids (g)	54.65	5.3	60.75	65.21	7.02	1.16	4,74	2.2	4.22	6.9	5.56	2.64	49.7	2.43	33.49	23.74	<70
MUFA (g)	*35.01*	*0.6*	*45.65*	*8.93*	*1.685*	*0.15*	*1,25*	*0.214*	*0.773*	*2.2*	*1.4*	*0.83*	*18.8*	*0.445*	*1.425*	*16.47*	
PUFA (g)	*12.28*	*1.3*	*7.92*	*47.17*	*2.778*	*0.56*	*2,16*	*0.616*	*2.134*	*2.5*	*2.1*	*0.89*	*21.8*	*1.258*	*0.366*	*2.21*	
SFA (g)	*4.93*	*3.2*	*4.46*	*6.13*	*1.459*	*0.25*	*0,67*	*0.192*	*0.723*	*1.2*	*0.5*	*0.52*	*7.6*	*0.406*	*29.698*	*4.02*	*<20*
Cholesterol(mg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Protein (g)	19.13	4	14.95	15.23	13.56	9.91	9.42	14.7	11.02	16.9	13.8	7.5	17.7	14.57	3.33	6.13	50
moisture (g)	5.87	4.48	5.31	4.07	11.29	10.09	10.37	10.95	8.67	0	11.5	11.4	4.24	11.02	46.99	n.a.	
Carbohydrates(g)	6.2	39.7	16.70	13.71	65.25	77.7	74.26	70.38	72.85	66.3	49.2	81.3	9.28	70.19	15.23	42.54	270
sugars (g)	*5.3*	*7.9*	*4.34*	*2.61*	*1.69*	*0.8*	*0.64*	n.a.	n.a.	n.a.	*5.92*	n.a.	*0.45*	n.a.	*6.23*	n.a.	
starch (g)	*0.11*	*31.8*	n.a.	*2.1*	*57.27*	n.a.	*73.3*	n.a.	n.a.	n.a.	*43.27*	*72.7*	*0.4*	n.a.	n.a.	*29.15*	
Dietary fiber (g)	8.35	7.1	9.7	6.7	6.7	15.6	7.3	9.1	8.5	10.6	7.9	3	7.9	10.7	9	17.4	25
Vitamin A* (μg)	0	0	1	1	0	0	11	1	0	0	0	0	n.a.	0	0	0	800
Vitamin E** (mg)	24	1.4	15.03	0.7	1.19	0.2	0.49	0.6	0.05	0.7	0.45	0.6	n.a.	0.79	0.24	10	12
Vitamin C (mg)	n.a.	0	6.3	1.3	4.2	0	0	0	0	0	0	0	0	0	3.3	6	80
Thiamin (mg)	0.21	0.18	0.643	0.34	0.116	0.19	0.385	0.591	0.421	0.76	0.2	0.39	0.791	0.364	0.066	0.23	1.1
Riboflavin (mg)	0.78	0.1	0.113	0.15	0.2	0.114	0.20	0.178	0.29	0.14	0.4	0.08	0.247	0.113	0.02	0.1	1.4
Niacin (mg)	5.3	n.a.	1.8	1.125	0.923	4.61	3.64	6.35	4.72	0.96	n.a.	6.8	4.52	6.843	0.54	1.8	50
Vitamin B6 (mg)	0.11	0.3	0.563	0.537	0.591	0.26	0.62	0.255	0.384	n.a.	0.2	0.51	0.79	0.23	0.054	n.a.	200
Biotin (μg)	64	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.5
Folate (μg)	70	85	113	98	82	23	19	n.a.	85		30	40	97	45	26	141	200
Vitamin B12 (μg)	0	0	0	0	n.a.	0	0	n.a.	0	0	0	0	0	n.a.	0	0	2.5
Pantothenic acid.(mg)	0.44	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.35	n.a.	1.5	0.05	n.a.	n.a.	n.a.	6
Sodium (mg)	10.36	10.6	11	2	4	9	35	6	5	2	61	6	2.31	8	20	37.63	<6
Potassium (mg)	767.25	591.6	680	441	508	280	287	446	195	429	780	223	468	388	356	519.2	2000
Calcium (mg)	248.25	47.3	114	98	159	29	7	24	8	54	79	21	96	27	14	69.54	800
phosphorous(mg)	524.88	87.6	290	346	557	221	210	386	285	523	230	303	604	401	113	232.23	700
Magnesium (mg)	258.13	39	163	158	248	79	127	134	114	177	210	143	324	136	32	86.88	375
Iron (mg)	3.59	1.06	4.7	2.91	7.61	2.5	2.71	4.41	3.01	4.72	7.8	1.7	14.6	4.44	2.43	3.41	14
Zinc (mg)	3.6	0.6	2.45	3.09	2.87	2.13	2.21	3.68	1.68	3.97	3.3	1.8	5.74	3.28	1.1	4.19	10
copper (mg)	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.63	n.a.	0.85	1.58	n.a.	n.a.	n.a.	1
Selenium (μg)	4	n.a.	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	<51.9	n.a.	n.a.	n.a.	55
iodide (μg)	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6	n.a.	22	<5	n.a.	n.a.	n.a.	150
Manganese (μg)	2.54	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.23	n.a.	n.a.	n.a.	2

A: Data extracted from Spanish Food Composition Database (RedBEDCA)
B: Data extracted from United States Department of Agriculture Database (USDA)
C: Data extracted from French agency for food environmental and occupational health and safety Database (Anses)
X :Recommended Daily Allowances. Data extracted from European Directive 90/496/CEE
RDA: Recommended Daily Allowances
*: Retinol equivalents
**: alfa-tocopherol equivalents
n.a.: data not available
MUFA: mono-unsaturated fatty acids
PUFA: poly-unsaturated fatty acids
SFA: saturated fatty acids

3/omega-6) in nut oil, which is related to anti-inflammatory, heart health, weight management and healthy cardiovascular system effects (Agostoni et al., 2011).
Although coconut is commonly classified as a nut, its composition does not follow the trend of this food group (Table 1), which means that not all of the above-mentioned health properties of nuts are associated with it. As can be seen in the chemical composition of coconut (Tables 1 and 4), the particularity of this traditional *milk* from the Asian, African and Pacific regions is its medium chain fatty acid (MCFA) lipid profile, which is similar to human milk (Chiewchan, Phungamngoen, & Siriwattanayothin, 2006); the most predominant is lauric acid (45-53% of total coconut fats) and this MCFA was reported to be antibacterial, antiviral and antifungal (Raghavendra & Raghavarao, 2010). In spite of the lipid profile being mostly saturated, Enig (2004) reported that MCFA are absorbed directly from the intestine and sent straight to the liver to be rapidly metabolized for energy production and, thus, they do not participate in the biosynthesis and transport of cholesterol. Furthermore, the high amount of antioxidants determines the long shelf-life of this vegetable *milk* and is good for the health. Other interesting health benefits are summarized in Table 4.
Tigernuts are another interesting source of raw material to be used for the production of vegetable *milks*. The major components (Table 1) of this tuber are complex carbohydrates, mainly starch and dietary fiber, which provide vegetable *milk* with low GI. Furthermore, the protein content is rich in arginine, which liberates hormones that produce insulin; thus being suitable for diabetics (Adejuyitan, 2011). Besides its antioxidant compounds, the lipid profile of tigernuts is similar to that found in olive oil; therefore, the derived *milk* has a positive effect on the cholesterol level. Other interesting health benefits are detailed in Table 4.
More specific properties and health benefits of each nut whose derived vegetable milk has been commercialized are summarized in Table 4.

3 Vegetable milk processing

Industrial vegetable *milk* processing is based on five main steps: grinding, water extraction, filtration, homogenization and pathogen removal treatment. Nevertheless, depending on the raw material and the desired final product characteristics, the process slightly differs. Thus, the processing is subsequently explained separately, taking into account the different groups of these above-mentioned *milks* commented upon.

3.1 Cereal *milk* processing

A typical flow diagram of cereal *milk* processing is shown in Figure 1. Before going through the extraction procedure, cereals are conditioned: this mostly refers to husking, washing and grain classification. Pre-conditioning is a requisite for Quinoa grain due to its saponins' content (toxic in high amounts and imparts a bitter taste). Mechanical abrasion and/or washing are sufficient to remove this unwanted compound (Brady et al., 2007).
Once the cereal grain is conditioned, it is submitted to a coarse dry grinding to facilitate the subsequent water extraction. This water extraction process is usually carried out in colloidal mills by adding hot water and the ground cereal at the same time. The colloidal mills are used to reduce the particle size of the solid in aqueous suspension by applying high levels of hydraulic shear to the process liquid. The amount of water added would depend on the final pre-established concentration. This step is carried out in hot conditions, on one hand, to ease the extraction of soluble compounds and, on the other hand, to provoke starch gelatinization and improve the subsequent enzymatic treatment. The main difference observed between these and other types of vegetable *milks* is this enzymatic treatment which they are submitted to after the extraction procedure. This step is needed to attain the low viscosity which the consumer demands of these products. This viscosity is provided mainly by starch and other polysaccharides after the thermal treatments.
After removing the non-extracted solids, the milky liquid obtained is then temperature ad-

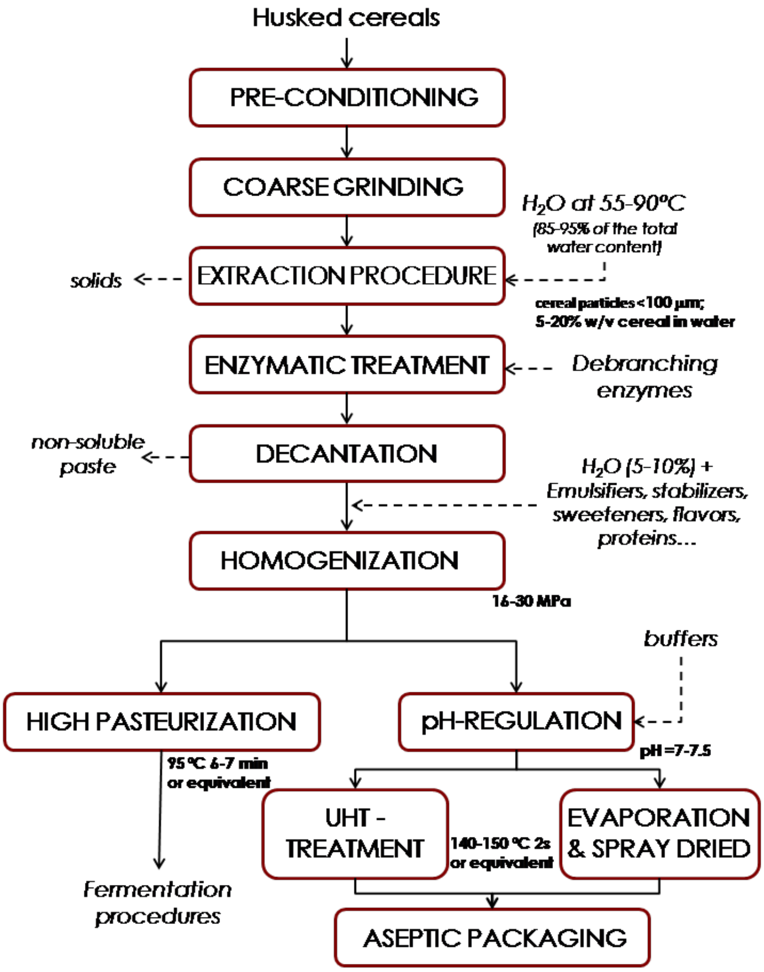

Figure 1: Typical cereal *milk* processing flow diagram.

justed and pH adjusted, with appropriate buffers, to the optimum level for the enzymatic treatment. The pH values, temperature and the time-remaining would depend on the types of enzymes used and those would be chosen taking into account the final product's desired viscosity, sugar content and/or texture parameters. Generally, enzyme composition comprises mainly α-amylase and β-amylase activities and is devoid of β-glucanase and proteinase activities, since glucans and proteins have interesting nutrient value and their degradation is not desirable (Triantafyllou, 2002). When the desired textural properties are reached, a homogenization process is applied to ensure physical stabilization during the product's shelf life. The usual homogenization pressures range between 16-30 MPa, although some researchers are studying the use of ultra-high pressures (UHPH, >150 MPa) in vegetable *milk* production (Bernat, Chafer, A., & González-Martínez, 2011; N. Cruz et al., 2007; Valencia-Flores, Hernandez-Herrero, Guamis, & Ferragut, 2013). Food additives, such as emulsifiers (lecithin), stabilizers (hydrocolloids), sweeteners, either natural (sucrose, fructose or glucose syrups from agave, corn, rice or wheat) or synthetic (acesulfame K, aspartame or sucralose) and, sometimes, flavoring agents (cocoa, soluble coffee, vanilla or cinnamon) are often introduced before the homogenization step. The amounts of these additives incorporated ranged from 0.4-2.5 %(w/v) in emulsifiers, 0.025-0.3 %(w/v) in stabilizers, 5-8 %(w/v) in sweeteners and 0.5-3 %(w/v) in flavoring agents (Erra, 2012; Pereyra & Mutilangi, 2012; Triantafyllou, 2002; Marti, Martinez, Miralles, & Perez, 2010). Further information on the ingredients used to formulate already commercialized cereal milks is shown in Table 2.

To ensure quality and safety, after having readjusted the pH to standard values of *milks* with buffers such as sodium carbonates, potassium carbonates, sodium hydroxides or potassium diphosphates (Erra, 2012), homogenized *milks* are either heat treated or spray dried and finally aseptically packaged. Heat parameters of temperature, time and pressure would be stipulated taking into account the type of product, the particle size, viscosity, initial microbial load and stability of components under thermal conditions. The inactivation conditions of the enzymes previously used is also a variable when choosing heat parameters, since this step is also used to eradicate the activities of residual enzymes. Ultra High Temperature (UHT) treatment is commonly chosen (140-150 ºC, 2 sec) or high pasteurization (95ºC > 6 min or equivalent treatment) might also be used when the *milks* product is to be fermente(Erra, 2012; Pereyra & Mutilangi, 2012; Marti et al., 2010; Triantafyllou, 2002).

The final milky product chemical composition of major components (protein, lipids and carbohydrates) in different types of cereals is summarized in Table 2. Considering these *milks* are to be used as substitutes for cow milk, it is remarkable that there is a high fiber content and a low lipid content with a better profile than standard milk.

3.2 Nut milk processing

The general industrial flow diagram of nut *milk* production is presented in Figure 2. The steps shown are mostly the same as in cereal *milk* processing but the enzymatic treatment is removed, since the low starch content of these nuts do not confer a negative effect on the viscosity of the final product.

Nut conditioning consists of washing and selection, plus a blanching treatment in order to facilitate both the further peeling of nuts and the initial microbial load reduction. In view of the fact that no enzymes are used, possible food additives such as emulsifiers, sweeteners, hydrocolloids and/or flavors can be introduced during the grinding step, and thereby facilitate the optimal dispersion of ingredients. The types of food additives chosen are the same as the ones mentioned in cereal *milk* processing.

The final milky product chemical composition of major components (proteins, lipids and carbohydrates) in different types of tree nuts is summarized in Table 2. In spite of the fact that the over 50 % of a nut's content is made up of lipids (Table 1), final contents end up with lower values than non-defatted cow milk, which varies from 3 to 5 % (w/v). Moreover, considering these vegetable *milks* are to be used for the same purposes as cow milk, the (MUFA+PUFA)/SFA ratio (SFA, Saturated Fatty Acids) is much higher than other animal milks and, hence, they are healthier. Almond *milk* stands out among other nut *milks* as being an appropriate alternative to cow milk, since, besides the lipid profile, it has a low ratio of Na/K and a balanced ratio of Ca/P (Luengo, 2009).

In the production of tigernut *milk*, the preconditioning step is more complex: in the extraction procedure, tigernuts need to be softened prior to the milling process (by rehydration with water for around 18 hours) and a preliminary germicidal treatment (active chlorine) is required to decrease the initial microbial load (it is a tuber) (CRDO: Consejo Regulador de la Denominación de Origen Chufa de Valencia, 2012; Sanful et al., 2009). Also, an enzymatic treatment is required due to the high starch content of this nut, as has been commented on above for the cereal *milks* manufacture.

In industrial coconut *milk* production, the coconut meal has to be obtained by shelling, paring and washing. After that, coconut meal is submitted to a blanching process reinforced with chemical agents, such as $NaHSO_3$, for different purposes: facilitate the removal of the brown testa, enhance oxidation stability due to inner enzyme denaturation and facilitate further grinding. Once coconut meat is ground and water

Table 2: Chemical composition of commercial vegetable *milks*. Average values shown are expressed per 100 mL of liquid product

VEGETABLE *MILK*	INGREDIENTS	BASIC CHEMICAL COMPOSITION (g 100 mL^{-1}) Proteins	Lipids TOTAL	Lipids MUFA	Lipids PUFA	Lipids SFA	Carbohydrates TOTAL	Carbohydrates SUGARS	Dietary fibre	Sodium	MAIN MANUFACTURERS
Almond	Water, almonds (7-8%), thickener (corn starch/maltodextrin), stabilizer (carrageenan/gellan gum), emulsifier (sunflower/soya lecithin), salt, almond flavor	**1.1-1.8**	**1.46-2.6**	0.8-4	0.42-1.4	0.3-0.6	**1-8**	0.1-1.6	**0.4-2**	**0.01-0.06**	*(1), (3), (6), (10), (12), (13), (14), (15)*
Chestnut	Water, chestnut (14%), sweetener (rice syrup/ agave syrup), thickener (maltodextrin), almond oil, natural flavor, salt	**0.05**	**3.5**	2.3	0.8	0.5	**6.2**	0.3	**2.4**	**0.03**	*-1*
Hazelnut	Water, hazelnut (7%), agave syrup, thickener (corn maltodextrin)	**0.6-0.8**	**1.5-2.8**	2	0.1	0.7	**6.5-8**	3.2-6	**0.42-0.9**	**0.175**	*(1), (15)*
Walnut	Water, walnut (7%), sweetener (agave syrup), corn maltodextrin	**1.2**	**1**	0.3	0.6	0.1	**7.4**	1.7	**0.4**	**0.02**	*(1), (12)*
Amaranth	Water, amaranth (7%), sweetener (agave syrup), thickener (corn maltodextrin), high oleic sunflower oil	**0.6**	**1.9**	1.1	0.3	0.5	**8**	n.a.	**0.3**	**0.05**	*-1*
Barley	Water, barley (17%), sunflower oil, salt	**0.5**	**1**	0.3	0.6	0.1	**11**	7	**0.5**	**0.09**	*-3*
Corn	Water, white corn (17%), sunflower oil, salt	**0.52**	**1.4**	0.7	0.5	0.2	**9.5**	6.5	**0.6**	**0.03**	*-3*
Kamut	Water, Kamut (12-14%), sunflower oil, salt	**0.65-0.7**	**0.8-1.45**	0.2-0.4	0.5-0.88	0.1-0.21	**7.5-20**	4.6-7.1	**0.4-0.5**	**0.04-0.09**	*(3), (4), (6), (12)*
Millet	Water, millet (15%), sunflower oil, salt	**0.7**	**1.2**	0.3	0.8	0.1	**9.8**	5.7	**0.4**	**0.09**	*-3*
Oat	Water, oat (8-14%), sunflower oil, salt	**0.5-1**	**0.7-1.6**	0.84-0.99	0.2-0.4	0.1-0.3	**4.75-11.8**	1.5-5.5	**0.44-0.9**	**0.04-0.1**	*(2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (15), (16)*
Quinoa	Water, quinoa (7-14%), sweetener (agave syrup), thickener (corn maltodextrin), stabilizer (pectin/carrageenan), sunflower oil, emulsifier (soya lecithin)	**1.5**	**2.8**	1.5	0.6	0.7	**3.7**	3.4	**0.6**	**0.2**	*(1), (2), (6)*
Rice	Water, rice (12-20%),stabilizer (carrageenan/xanthan gum), sunflower/rape seed oil, salt	**0.12-0.8**	**0.9-3**	0.33-1	0.11-1.7	0.1-0.37	**4.6-15.6**	4.3-7.1	**0.12-0.15**	**0.04-0.1**	*(2), (3), (4), (5), (6), (7), (8), (11), (12), (15), (16)*
Sesame	Water, sesame (7%), sweetener (agave syrup), thickener (corn maltodextrin), high oleic sunflower oil	**0.6**	**2.4**	1.4	0.5	0.5	**6.7**	n.a.	**0.2**	**0.01**	*-1*
Spelt	Water, spelt (14-15%), sunflower oil, salt	**0.2-0.7**	**1-1.4**	0.3-0.37	0.8-0.87	0.1-0.16	**8.4-9.6**	4-7	**0.2-0.7**	**0.05-0.13**	*(2), (3), (5), (6)*
Coconut	Coconut cream(10%), sweetener (cane sugar), natural flavor, stabilizer (carrageenan/guar gum), salt	**0.2-0.7**	**1.9-2.4**	0.1	n.a.	1.4-2.3	**0.9-3.7**	0.4-1	**0.4-1.1**	**0.02-0.1**	*(13), (14)*
Tigernut	Water, tigernuts (10-14%), sweetener (agave syrup/sucralose), thickener (corn maltodextrin/tapioca starch), stabilizer (carrageenan/ carboxymethyl cellulose)	**0.4-0.7**	**2-2.4**	1.1-1.6	0.19-0.3	0.4-0.6	**5.3-8.3**	4.5-6.5	**0.67-1**	**0.02-0.06**	*(1), (3), (12)*

(1) Nutriops S.L. (Spain) *(2) Soria Natural® (Spain)*
(3) Isola Bio®; Abafoods S.L. (Italy) *(4) La finestra sul Cielo® (Italy)*
(5) LIMA® (France) *(6) The Bridge S.L. (Italy)*
(7) Alinor® (Italy) *(8) Naturgreen®; Laboratorios Almond S.L. (Spain)*
(9) OALTY® (Sweden) *(10) Liquats vegetals S.L. (Spain)*
(11) Vegetalia® (Spain) *(12) AMANDIN®/Costa Concentrados Levantinos, S.A. (Spain)*
(13) So-delicious® dairy-free (USA) *(14) Silk® (USA)*
(15) Pacific® (USA) (16) Vitasoy International Holdings Ltd. (Hong Kong)

n.a.: data not available *MUFA: mono-unsaturated fatty acids*
PUFA: poly-unsaturated fatty acids *SFA: saturated fatty acids*

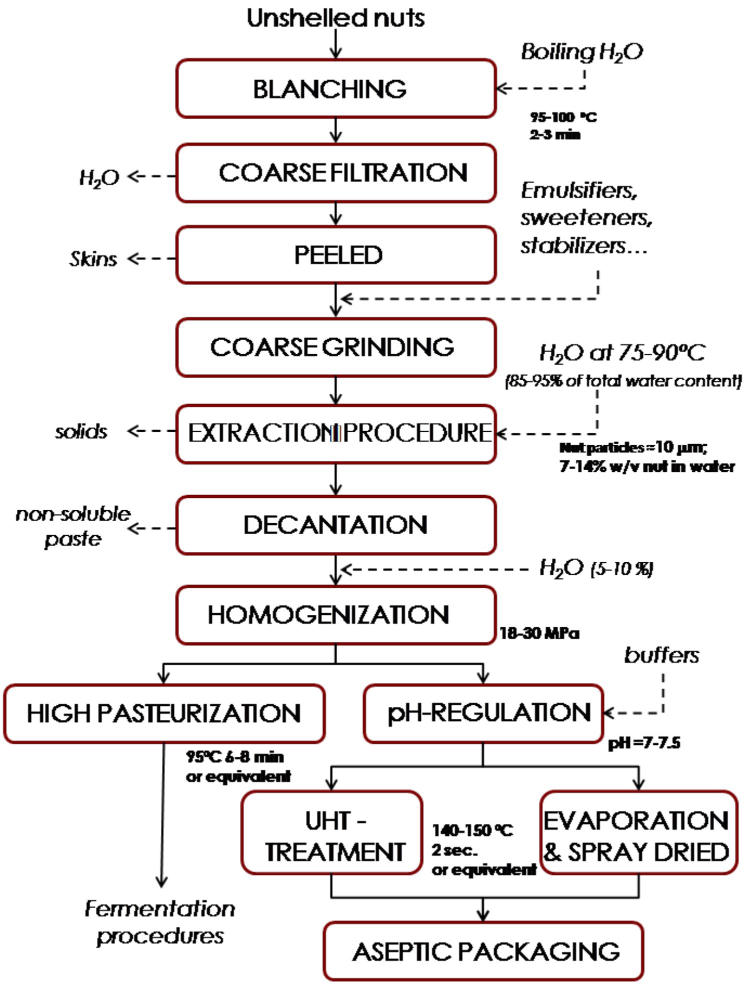

Figure 2: Typical nut *milk* processing flow diagram.

extraction is developed, the milky liquid is finally filtrated using double layers of cheese cloth (Mepba, Achinewhul, & Pillay, 2009).

The major technological problem found during the processing or shelf life of these cereals and nut derived *milks* is related with the low physical stability of the liquid dispersion, usually with low viscosity, which promotes the phase separation of the unstable fat globules caused by flocculation and coagulation phenomena in a short period of time. Moreover, fibers and non-soluble material will also separate, either by sedimentation or floatation, thus contributing to the watery effect of the product. The employment of an optimal thermal treatment and homogenization pressures during the *milk* processing, the addition of both amphiphilic compounds and hydrocolloids or the use of UHPH could contribute to the development of an excellent product with desirable sensory attributes. Using UHPH allows for a longer shelf life of the product, since greater physical stability is achieved mainly due to a reduction in the size of the fat globule that prevents coalescence. Figure 3 shows pictures of hazelnut *milk* obtained by means of the Confocal laser scanning microscopy (CLSM) technique in which the effect of UHPH is proved; as can be seen, almost all the fat globules in untreated

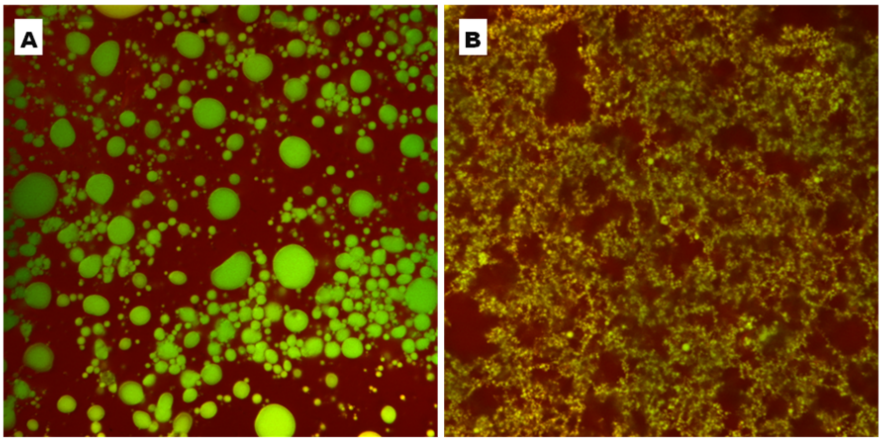

Figure 3: Confocal pictures of hazelnut *milk* non-treated (A) and homogenized at 172 MPa (B), where fat globules appeared green-yellow colored. *Source*: personal compilation, University of Valencia

milk (Fig. 3A) are aggregated, while in that which has been UHPH-treated (Fig 3A), not only are the fat globules non-aggregated but they are also distributed, forming a kind of network that enhances physical stability. Sometimes homogenization pressures are also capable of reducing the microbial load of the product prior to the thermal treatment, if they are greater than 200 MPa (N. Cruz et al., 2007; Pereda, Ferragut, Quevedo, Guamis, & Trujillo, 2007; Valencia-Flores et al., 2013). Despite the advantages, this emergent technology is being only used in a laboratory and pilot-scale due to the high investment costs. Hence, as can be seen in Table 2, the vegetable *milks* processing industry normally use hydrocolloids and emulsifiers to prevent phase-separation in developed products.

4 Fermentation of vegetable *milks*

Besides the direct consumption of vegetable *milks*, they might be also used as raw materials to develop yogurt-type products, as has been done with soy *milk*. Hence, these newly fermented products would satisfy a market sector focused on the current consumers' demand of non-dairy products.

In this regards, nut and cereal *milks* are considered as good substrates for the growth of different strains, owing to the presence of non-digestible components with prebiotic properties in both vegetable matrices. Thus, starch and fiber materials are reported to enhance the physical stability of the fermented vegetable *milk* and to promote the survival of the starters used, not only due to their nutritional contribution but also, since fibers are resistant to gastric juices, they act as protective barriers within the human gastrointestinal tract, (Bosnea et al., 2009; Patel, Pandiella, Wang, & Webb, 2004; Perrin, Grill, & Schneider, 2000; Wang, Conway, Brown, & Evans, 1999). Nevertheless, the ability of the starter microorganism to grow in these vegetable raw materials varies largely with the strain. Therefore, studies into bacterial survival are required prior to processing the fermented product.

Most of these innovative fermented products found in the literature have been developed by using probiotic bacteria from Bifidobacteria, Lactobacillus and Streptococcus genera. If probiotic bacteria are used as starter microorganisms, the newly designed product would have an added value, owing to the health benefits that these type of bacteria can exert. Although oat is often used as a raw material, other matrices have also been studied, such as almond, hazelnut or rice. A list of these has been summarized in Table 3.

Table 3: Main characteristics of nut and cereal fermented products found in the literature.

Raw material	Probiotic bacteria used	Growth enhancer (Prebiotic) present and/or added	Reference
Malt, barley and wheat	L. *plantarum*, L. *acidophilus*	FOS, β-glucan, starch and other dietary fibers	D Charalampopoulos, Pandiella, and Webb, 2002
	L. *plantarum*	FOS, β-glucan, starch and other dietary fibers	Dimitris Charalampopoulos and Pandiella, 2010
Wheat, oat and barley	L. *plantarum*	FOS, β-glucan, starch and other dietary fibers	Salmeron, Fucinos, Charalampopoulos, and Pandiella, 2009
	L. *plantarum*	β-glucan and other dietary fibres	Angelov, Gotcheva, Kuncheva, and Hristozova, 2006 ; Gupta, Cox, and Abu-Ghannam, 2010
Oat	L. *reuteri*, L. *acidophilus*, B. *bifidum*	β-glucan and other dietary fibres	Martensson, Oste, and Holst, 2002
Rice-based	L. *plantarum*, L. *paracasei* ssp.*casei*, L. *acidophilus*	Inulin, β-glucan and other dietary fibers	Gokavi, Zhang, Huang, Zhao, and Guo, 2005
	L. *acidophilus*, L. *casei* ssp. *rhamnosus*	Starch	Boonyaratanakornkit and Wongkhalaung, 2000
	B. *lactis*	Starch, pentosan and other dietary fibers	McMaster, Kokott, Reid, and Abratt, 2005
Maize	L. *paracasei*, L. *casei*, L. *rhamnosus*, L. *acidophilus*	Inulin, starch, pentosan and other dietary fibers	Nyanzi, Jooste, Abu, and Beukes, 2010
Maize and barley	L. *reuteri*, L. *acidophilus*, L. *rhamnosus*	Starch, pentosan and other dietary fibers	Helland, Wicklund, and Narvhus, 2004
Emmer wheat	L. *rhamnosus*, other LAB	FOS and other dietary fibers	Coda, Rizzello, and Gobbetti, 2010
Coconut	L. *paracasei*, B. *lactis*	Starch and dietary fiber	Correa, Castro, and Saad, 2008
Chestnut	L. *rhamnosus*	Starch and other dietary fibers	Blaiotta, Di Capua, Coppola, and Aponte, 2012
Walnut	Kefir grain microorganisms with potentially probiotic effects	Starch and other dietary fibers	Cui, Chen, Wang, and Han, 2013
Tigernut, almond or hazelnut	B. *lactis*, S. *thermophilus*	Starch, FOS and other dietary fibers	Marti, Martinez, Miralles, and Perez, 2005

B: Bifidobacteria **L**: Lactobacillus **S**: Streptococcus

4.1 Processing of fermented vegetable *milk*

General industrial processing used to develop nut and cereal fermented vegetable products is based on four main steps: the procedure to obtain vegetable *milk* previously commented on above (Figures 1 and 2), conditioning the *milk* until the optimal starters' growing temperature is reached, the inoculation and incubation procedures (fermentation) and cooling to 4 ºC. Nevertheless, depending on the raw material, the type of starters used and the final product features, the whole process may differ.
Some additives are frequently introduced into the vegetable matrix, mainly sugars and prebiotics (as growth enhancers), to promote the viability of bacteria and to reduce the length of the fermentation process (in order to avoid cross-contamination problems). Mono and oligosaccharides, some prebiotics such as inulin, β-glucans and dietary fibers have been the growth enhancers most commonly used by different authors (Akalin, Tokusoglu, Gonc, & Aycan, 2007; Gokavi, Zhang, Huang, Zhao, & Guo, 2005; Ozer, Akin, & Ozer, 2005; Rosburg, Boylston, & White, 2010; Sendra et al., 2008). Potentially, prebiotics are naturally present in both cereals and nuts (i.e. dietary fiber); nevertheless, prebiotic compounds are sometimes added in order to increase the product's health benefits or its technological properties, since the majority are able to increase the viscosity of the *milk*.On the other hand, hydrocolloids, such as carrageenan and xanthan gum, are often added to prevent syneresis and, thus, ensure the physical stability of the product during the stated shelf life. Nonetheless, if the raw material used naturally contains these types of compounds, it might not be necessary to add them during the industrial processing (i.e. β-glucans present in oat *milkz*).
Prior to the addition of the starter inoculum, pathogen-free *milks* must be conditioned to reach the fermentation temperature. This is usually around 37 ºC, but it depends on the optimal growth temperature of the starter bacteria used. With regards to the fermentation time, much longer is usually needed than during standard cow milk yogurt production, since potential probiotic bacteria (type of bacteria currently chosen to develop these foodstuffs due to the added value on the final product) have more complex nutritional requirements (Severson, 1998), especially when growing in vegetable matrices. The reported fermentation times have been found to be around 16-24 h if no growth enhancers are used in the formulation (Dimitris Charalampopoulos & Pandiella, 2010; D Charalampopoulos, Pandiella, & Webb, 2002; Coda, Rizzello, & Gobbetti, 2010; Correa, Castro, & Saad, 2008; Blaiotta, Di Capua, Coppola, & Aponte, 2012; Cui, Chen, Wang, & Han, 2013; Gokavi et al., 2005; Gupta, Cox, & Abu-Ghannam, 2010; Martensson, Oste, & Holst, 2002). The fermentation procedure finishes when the pH value of *milks* reaches 4.2-4.5. Immediately afterwards, the fermented products are sealed, cooled to 4 ºC and stored at refrigeration temperatures.
The major challenges affecting these fermented products are related to the sensory quality (appearance and texture) and the resistance of the probiotic microorganisms. Most of these fermented products might have physical stability problems caused by phase separation between components (usually proteins coagulate, forming a non-continuous weak gel, and serum separation occurs at the very beginning of storage time or during storage period). This structure can be observed in Figure 4, where the microstructure is shown of an oat fermented milk with probiotic L. *reuteri* and S. *thermophiles* obtained by using CLSM. As can be observed, the aqueous continuous phase is not completely entrapped in the non-continuous protein-fiber network.
The appearance of these products is often very similar to that observed in a low-fat stirred yogurt. To promote physical stability during the acidification process, hydrocolloids are generally used, as has been commented on above. The most common hydrocolloids used as thickening agents are xanthan gum, modified starches, pectin and cellulose derivatives, among others. Nevertheless, other tools have been used to promote better textural properties. For instance, Martensson, Oste, and Holst (2000) selected strains able to produce exopolysaccharides (EPS) in order to obtain oat-based fermented products. Yoghurts with EPS-producing bacterial strains showed higher viscosity and less phase separa-

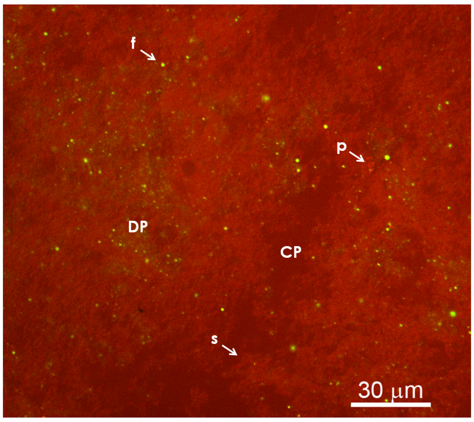

Figure 4: Microstructure obtained by CLSM of fermented oat *milk* with a mixed culture of L. *reuteri* and S. *thermophilus*. (**CP**: Continue phase; **DP**: Dispersed phase; f: fat globule; s: starters + other fibers). *Source*: personal compilation, University of Valencia

tion in comparison with yoghurts made with strains not producing EPS. This structural property would give rise to a new generation of in situ produced thickeners. This is of general interest, as there is an increasing demand from manufacturers to decrease the addition of stabilizers in yoghurt products.

N. S. Cruz et al. (2009) instead, studied the effect of UHPH treatments (around 250-300 MPa) in soy milk on the fermentation processing. This technology is quite similar to the conventional high-pressure homogenization used in the food industry but considerably higher pressures are applied. Some benefits have been reported for its application in the food industry as it causes interesting changes in structural components and increases the shelf-life of liquid products. The results showed that UHPH soy-yogurts displayed greater firmness and higher water holding capacity than gels produced from conventional homogenized samples.

On the other hand, to enhance the resistance of probiotics during the product's entire shelf-life, new approaches are being taken by different researchers, such as the use of oxygen-impermeable containers, two-step fermentations and the incorporation of micronutrients into the matrices (peptides and/or amino-acids). Finally, the use of microencapsulation techniques has also been studied as a means of promoting the survival of the probiotic bacteria through the gastrointestinal tract (ability to resist gastric juices and bile) (Soccol et al., 2010).

5 Conclusions

The development of nut and cereal products, unfermented or fermented by means of probiotic bacteria, fully meets the current trend towards an increased consumer demand for healthier products, mainly because of the close relationship between the consumption of vegetable products and the prevention of cancer, atherosclerosis or inflammatory diseases, as has been claimed by some official American and European organizations. In this sense, the demand for and consumption of these products is expected to rise in the next few years, especially in that section of the population which is more aware of health issues. Moreover, and taking into account the low requirements for producing nuts and cereals, the high market potential of these products could be used in the not-to-far future to increase wealth in developing countries by implementing nut and cereals crops such as almonds and oats in non-cultivated lands.

In the development of these products, some important technological deficiencies have been found, mainly related to the product's physical stability during its entire shelf-life. To this end, the optimization of processing techniques must be encouraged and more studies focusing on the microstructure and arrangement of the different components of the products after processing are needed in order to clarify and understand how to improve the appearance and texture of the final product. These studies would also allow a reduction in the amount of additives (hydrocolloids and/or emulsifiers) and thus reduce the economic costs. In the particular case of fermented products, the use of starter microorganisms which are able to both improve the quality (by synthesizing enhanced flavors and providing optimal textures) and exert health benefits for consumers (i.e. probiotics) is the main challenge to be faced in future studies.

Table 4: Main features and health benefits of the raw materials commercially used for producing vegetable *milks*

Raw material	**Product features**	**Health benefits**	**References**
Almond	§ Good source (arranged by importance) of Vit. E, K, Mn, Mg, Cu, P, dietary fiber, riboflavin and protein.	§ Hypocholesterolemic benefits	C.-Y. Chen et al., 2006; Hollis and R. Mattes, 2007; Iacono, Lospalluti, Licastro, and Scalici, 2008; Li et al., 2009; Mandalari, Nueno-Palop, Bisignano, Wickham, and Narbad, 2008; Rajaram, Connell, and Sabate, 2010; Vinson and Cai, 2012
(nut)	§ Good lipid profile, mainly MUFA § Important source of phytonutrients, mainly flavonoids and proanthcyanidins. § Lactose-free; low digestible carbohydrate § Cholesterol-free § High digestibility § Low GI § Low Na content	§ Protective effect against CVD § Antioxidant properties § Electrolite balance contribution § Glucorregulation properties § Prebiotic effect § Anti-inflammatory properties § Possible contribution to protect against some cancers, such as colon cancer § Suitable for celiacs and lactose intolerants	
Chestnut	§ Good source of K, Mg, Fe, Ca, Mn, Cu, dietary fiber, and protein rich in leucine and arginine.	§ Hypocholesterolemic benefits	O. Borges, Goncalves, de Carvalho, Correia, and Silva, 2008; O. P. Borges, Carvalho, Correia, and Silva, 2007; De Vasconcelos, Bennett, Rosa, and Ferreira-Cardoso, 2010
(nut)	§ Low-fat content § Good lipid profile, mainly PUFA and followed by MUFA. § Important amounts folates, thiamin and riboflavin § Important source of phenolic compounds § Lactose-free; low available carbohydrate § Cholesterol-free § High digestibility § Low GI § Low Na content	§ Protective effect against CVD § Antioxidant properties § Electrolite balance contribution § Glucorregulation properties § Prebiotic effect § Possible contribution in protection against some cancers, such as colon cancer § Suitable for celiacs and lactose intolerants	

Table 4 – *Continued from previous page...*

Raw material	**Product features**	**Health benefits**	**References**
Hazelnut	§ Good source of Vit. E, K, Fe, Ca, Mg, Zn, dietary fiber, and protein rich in arginine and leucine.	§ Hypocholesterolemic benefits	Alasalvar, Shahidi, Liyanapathirana, and Ohshima, 2003; Durak et al., 1999; Koksal, Artik, Simsek, and Gunes, 2006; Li et al., 2009; Mercanligil et al., 2007; Ozdemir et al., 2001, Tey et al., 2011
(nut)	§ Good lipid profile, mainly MUFA.	§ Protective effect against CVD	
	§ Important amounts of niacin, Vit.B1, Vit.B2, Vit.B6 and ascorbic acid.	§ Antioxidant properties	
	§ Important source of bioactives and phytochemicals and antioxidant phenolics (mainly caffeic acid)	§ Electrolite balance contribution	
	§ Lactose-free; low available carbohydrate	§ Glucorregulation properties	
	§ Cholesterol-free	§ Prebiotic effect	
	§ High digestibility	§ Possible contribution protection against some cancers, such as colon or prostate cancers	
	§ Low GI	§ Suitable for celiacs and lactose intolerants	
	§ Low Na content		
Walnuts	§ Good source of K, P, Mg, Fe, Mn, Cu, Zn, dietary fiber, and protein rich in arginine.	§ Hypocholesterolemic benefits	Almario, Vonghavaravat, Wong, and Kasim-Karakas, 2001; Banel and F. B. Hu, 2009; Chisholm et al., 1998; Elaine and Feldman, 2002; Li et al., 2009; Sze-Tao and Sathe, 2000; Vinson and Cai, 2012; Zambón et al., 2000
(nut)	§ Good lipid profile, mainly PUFA (linoleic and g-linolenic acids).	§ Protective effect against CVD	
	§ Appreciable amounts of Vit.E, niacin, thiamin, riboflavin and folic acid.	§ Antioxidant properties	
	§ Important source of bioactives and phytochemicals	§ Electrolite balance contribution	
	§ Cholesterol-free	§ Glucorregulation properties	
	§ High digestibility	§ Prebiotic effect	
	§ Low GI	§ Anti-inflammatory properties	
	§ Low Na content	§ Possible contribution in protection against some cancers, such as colon or prostate cancers	
		§ Suitable for celiacs and lactose intolerants	

Table 4 – *Continued from previous page...*

Raw material	**Product features**	**Health benefits**	**References**
Amaranth	§ Good source of Vit.E, Ca, Mg, K, P, Fe and Zn	§ Hypocholesterolemic benefits	Alvarez-Jubete, Arendt, and Gallagher, 2010; Caselato-Sousa and Amaya-Farfan, 2012; Marcone, Kakuda, and Yada, 2003; Sanz-Penella, Wronkowska, Soral-Smietana, and Haros, 2013
(cereal)	§ High content in both soluble and insoluble fiber	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA (linoleic acid), followed by MUFA (oleic acid)	§ Antioxidant properties	
	§ Good protein source rich in lysine and methionine	§ Electrolite balance contribution	
	§ High phytosterol content, mainly b-sitosterol	§ Glucorregulation properties	
	§ High levels of tocotrienols and squalene (cholesterol-lowering comp.)	§ Prebiotic effect	
	§ Important amounts of Vit.C, riboflavin and niacin.	§ Possible contribution in protection against some cancers such as colon cancer	
	§ Important source flavonoids and phenolic compounds.	§ Suitable for celiacs, diabetics and lactose intolerants	
	§ Source of Lunasin (antitumoral peptide)	§ Antitumor effects	
	§ Lactose-free; low available carbohydrate	§ Anti-inflammatory properties	
	§ Gluten-free	§ Anti-anemic effects	
	§ Cholesterol-free		
	§ High digestibility		
	§ Low GI		
Barley	§ Good source of Ca, Mg, K, P, Fe and Zn	§ Hypocholesterolemic benefits	AbuMweis, Jew, and Ames, 2010; Ames and Rhymer, 2008; Baik and Ullrich, 2008; K. D. Kaur et al., 2011; Thondre, Ryan, and Henry, 2011; J. L. Ward et al., 2008.
(cereal)	§ High content in dietary fiber, rich in b -glucans	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA	§ Antioxidant properties	
	§ Good protein source rich in lysine	§ Electrolite balance contribution	
	§ Important source of tocopherols and tocotrienols (cholesterol-lowering comp.)	§ Glucorregulation properties	
	§ Important amounts of group B vitamins, mainly nicacin, riboflavin folate and thiamin.	§ Prebiotic effect	

Table 4 – *Continued from previous page…*

Raw material	Product features	Health benefits	References
	§ Good source of phenolic compounds § Lactose-free; low available carbohydrate § Gluten-free § Cholesterol-free § High digestibility § Low GI	§ Possible contribution in protection against some cancers, such as colon cancer § Suitable for diabetics and lactose intolerants § Anti-anemic effects	
Kamut **(cereal)**	§ Good source of Vit.E, Ca, Mg, K, P, Fe, Mn, Se and Zn § High content in dietary fiber § Good lipid profile, mainly PUFA § Good protein source § High levels of, tocopherols and tocotrienols § Good source of b-carotene and group B Vit., mainly thiamin, riboflavin, nicacin, B6 Vit. and folates. § Important source of phenolic compounds. § Lactose-free; low available carbohydrate § Cholesterol-free § High digestibility § Low GI	§ Hypocholesterolemic benefits § Protective effect against CVD § Antioxidant properties § Glucorregulation properties § Prebiotic effect § Possible contribution in protection against some cancers, such as colon cancer § Suitable for diabetics and lactose intolerants § Anti-anemic effects	Canavari, Lombardi, and Spadoni, 2009; Dinelli et al., 2009; Marotti et al., 2012; Piergiovanni, Simeone, and Pasqualone, 2009.
Maize **(cereal)**	§ Good source of Vit.A, E, thiamin, niacin and also K, P, Mg, Fe, Zn and dietary fiber. § Good lipid profile, mainly PUFA (linoleic acid) followed by MUFA (oleic acid). § Important source of pantothenic and folic acids § Important source of phenolic compounds, mainly ferulic acid. § Lactose-free; low available carbohydrate (they are in the form of starch, fiber and pentosan) § Gluten-free § High digestibility § Low GI § Cholesterol-free	§ Hypocholesterolemic benefits § Protective effect against CVD § Antioxidant properties § Suitable for celiacs, diabetics and lactose intolerants § Possible contribution in protection against some cancers, such as colon cancer	Del Pozo-Insfran, Brenes, Saldivar, and Talcott, 2006; K. D. Kaur et al., 2011

Table 4 – *Continued from previous page...*

Raw material	**Product features**	**Health benefits**	**References**
Millet	§ Good source of Ca, Mg, K, P, Fe Zn	§ Hypocholesterolemic benefits	Chandrasekara and Shahidi, 2011; Devi, Vijayabharathi, Sathyabama, Malleshi, and Priyadarisini, 2011; Hegde, Rajasekaran, and Chandra, 2005; Léder, 2004; K. D. Kaur et al., 2011;
(cereal)	§ High content in insoluble dietary fiber	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA (linoleic acid), followed by MUFA	§ Antioxidant properties	
	§ Important amounts of group B vitamins, mainly thiamin, riboflavin, folate and niacin.	§ Glucorregulation properties	
	§ Good source of phenolic compounds	§ Prebiotic effect	
	§ Lactose-free; low available carbohydrate	§ Possible contribution in protection against some cancers, such as colon cancer	
	§ Gluten-free	§ Suitable for celiacs, diabetics and lactose intolerants	
	§ Cholesterol-free	§ Anti-anemic effects	
	§ Low GI		
Oat	§ Good source of Vit.E, Ca, Mg, K, P, Fe, Cu and Zn	§ Hypocholesterolemic benefits	Biel, Bobko, and Maciorowski, 2009; Daou and Zhang, 2012; Jing and X. Hu, 2012; K. D. Kaur et al., 2011; Kemppainen, Heikkinen, Ristikankare, Kosma, and Julkunen, 2009; Butt, Tahir-Nadeem, Khan, Shabir, and Butt, 2008; Thompson, 2003; J. L. Ward et al., 2008;
(cereal)	§ High content in dietary fiber, rich in b-glucans	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA	§ Antioxidant properties	
	§ Good protein source rich in lsulfur aminoacids, such as methionine and cystine (essential aminoacids)	§ Electrolite balance contribution	
	§ Important amounts of group B vitamins, mainly nicacin, riboflavin and thiamin.	§ Glucorregulation properties	
	§ Good source of tocopherols and phenolic compounds	§ Prebiotic effect	
	§ Lactose-free; low available carbohydrate	§ Possible contribution in protection against some cancers, such as colon cancer	
	§ Gluten-free	§ Suitable for celiac, diabetics and lactose intolerants	

Table 4 – *Continued from previous page...*

Raw material	**Product features**	**Health benefits**	**References**
	§ Cholesterol-free	§ Antimicrobial and immune effects	
	§ Low Na content	§ Anti-anemic effects	
	§ High digestibility		
	§ Low GI		
Quinoa	§ Good source of Vit.E, Na, Ca, Mg, K, P, Fe Zn	§ Hypocholesterolemic benefits	Abugoch James, 2009; Alvarez-Jubete et al., 2010; Brady et al., 2007; Chauhan, Eskin, and Mills, 1999; Zhu et al., 2002.
(cereal)	§ High content in dietary fiber	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA (linoleic acid), followed by MUFA(oleic acid)	§ Antioxidant properties	
	§ Good protein source rich in lysine and methionine	§ Glucorregulation properties	
	§ High phytosterol content.	§ Prebiotic effect	
	§ High levels of squalene (cholesterol-lowering comp.)	§ Possible contribution in protection against some cancers, such as colon cancer	
	§ Important amounts of group B vitamins, mainly riboflavin folate and thiamin.	§ Suitable for celiacs, diabetics and lactose intolerants	
	§ Source of bioactive peptides	§ Antitumor effects	
	§ Lactose-free; low available carbohydrate	§ Anti-inflammatory properties	
	§ Gluten-free	§ Anti-anemic effects	
	§ Cholesterol-free		
	§ High digestibility		
	§ Low GI		
Rice	§ Good source of K, Ca, Mg, P, Fe, Zn, Se and Si.	§ Hypocholesterolemic benefits	Biswas, Sircar, Mitra, and De, 2011; Cicero and Gaddi, 2001; Faccin, Miotto, do Nascimento Vieira, Barreto, and Amante, 2009; Sierra et al., 2005.
(cereal)	§ Low Na content	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA (linoleic and g-linolenic acids), followed by MUFA (oleic acid)	§ Antioxidant properties	
	§ Important source of phytosterols, especially b-sitosterol and g-oryzanol (oxidation inhibitors)	§ Electrolite balance contribution	
	§ Important source of tocopherols (Vit.E) and tocotrienols (LDL-cholesterol lowering)	§ Glucorregulation properties	
	§ Important amounts of group B vitamins, mainly nicacin, riboflavin, folate, thiamin, B6 Vit., and panthothenic ac.	§ Suitable for celiacs, and lactose intolerants	

Table 4 – *Continued from previous page...*

Raw material	Product features	Health benefits	References
	§ Good source of phenolic compounds	§ Antitumor effects	
	§ Lactose-free	§ Anti-inflammatory properties.	
	§ Gluten-free		
	§ Cholesterol-free		
	§ High digestibility		
Sesame	§ Good source of Vit. E Ca, Mg, K, P, Fe, Zn and Cu.	§ Hypocholesterolemic benefits	Cooney, Custer, Okinaka, and Franke, 2001; Sirato-Yasumoto, Katsuta, Okuyama, Takahashi, and Ide, 2001; Wu, Kang, Wang, Jou, and Wang, 2006;
(cereal)	§ High content in dietary fiber	§ Protective effect against CVD	
	§ Good lipid profile, mainly PUFA (rich in linoleic)	§ Antioxidant properties	
	§ Good protein source	§ Electrolite balance contribution	
	§ High content in lignan (phytostrogen)	§ Glucorregulation properties	
	§ Important amounts of group B vitamins, mainly nicacin, riboflavin folate and thiamin.	§ Prebiotic effect	
	§ Good source of phenolic compounds	§ Possible contribution in protection against some cancers, such as colon cancer	
	§ Lactose-free; low available carbohydrate	§ Suitable for celiacs, diabetics and lactose intolerants	
	§ Gluten-free		
	§ Cholesterol-free		
	§ High digestibility		
	§ Low GI		
Spelt	§ Good source of Vit.E, Ca, Mg, K, P, Fe, Mn and Zn	§ Hypocholesterolemic benefits	J. L. Ward et al., 2008; Zielinski, Ceglinska, and Michalska, 2008; Marques et al., 2007, Ruibal-Mendieta et al., 2005; Ranhotra, Gelroth, Glaser, and Lorenz, 1996.
(cereal)	§ High content in dietary fiber	§ Protective effect against CVD	
	§ Low Na content	§ Antioxidant properties	
	§ Good lipid profile, mainly PUFA (linoleic acid), followed by MUFA (oleic acid)	§ Electrolite balance contribution	
	§ Good protein source	§ Glucorregulation properties	
	§ High levels of, tocopherols and tocotrienols	§ Prebiotic effect	
	§ Good source of group B Vit., mainly thiamin, riboflavin, nicacin, B6 Vit. and folates.	§ Possible contribution in protection against some cancers, such as colon cancer	
	§ Important source of phenolic compounds.	§ Suitable for diabetics and lactose intolerants	
	§ Lactose-free; low available carbohydrate	§ Anti-anemic effects	

Table 4 – *Continued from previous page...*

Raw material	**Product features**	**Health benefits**	**References**
	§ Cholesterol-free § High digestibility § Low GI		
Coconut	§ Good source of Vit.C and also K, P, Mg and Fe.	§ Hypocholesterolemic benefits	DebMandal and Mandal, 2011; Enig, 2004; Raghavendra and Raghavarao, 2010; Sri Lanka Medical Association, 2006.
(fruit)	§ Rich in MCFA, mainly lauric acid § Important source of polyphenols § Lactose-free § Cholesterol-free § High digestibility § Low GI	§ Protective effect against CVD § Antiviral, antibacterial and antifungical properties § Antioxidant properties § Antithrombotic and antiatheroclerotic effects § Inmunostimulatory properties § Suitable for celiacs and lactose intolerants	
Tigernut	§ Good source of Vit.E, Ca, Na, K, P, Cu and dietary fiber.	§ Hypocholesterolemic benefits	Adejuyitan, 2011; Arafat, Gaafar, Basuny, and Nassef, 2009; Sanchez-Zapata, Fernandez-Lopez, and Angel Perez-Alvarez, 2012; Sanful et al., 2009.
(tuber)	§ Good lipid profile, mainly MUFA (oleic acid) and followed by linoleic acid. § Important amounts of Vit.C, folates, thiamin and riboflavin § Important source of bioactives and phytochemicals and phenolic compounds. § Lactose-free; low available carbohydrate § Cholesterol-free § High digestibility § Low GI	§ Protective effect against CVD § Antioxidant properties § Glucorregulation properties § Prebiotic effect § Possible contribution in protection against some cancers, such as colon cancer § Suitable for celiacs and lactose intolerants	

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