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REVIEW ARTICLE

How well do plant based alternatives fare nutritionally compared to cow's milk?

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Abstract Due to the issues like lactose intolerance and milk allergy arising from the consumption of cow's milk, there has been an increased demand in the plant based alternative milks around the world. Food industry has addressed these demands by introducing various milk beverages which are promoted as alternatives coming from plant sources which include almond milk and soy milk. Though they are popularly advertised as healthy and wholesome, little research has been done in understanding the nutritional implications of consuming these milk beverages in short term and long term. Further, consumers associate these alternatives to be a direct substitute of cow's milk which might not be true in all cases. This review tries to address the issue by outlining the differences between cow's milk and commercially available alternative milks in terms of their nutrient content. Though various plant based alternate milks have been studied, only the four most consumed milk beverages are presented in this review which are consumed widely around the world. A complete nutritional outline and the corresponding health benefits of consuming these plant based milk beverages have been discussed in detail which could help the consumers make an informed decision.

Keywords Milk beverages · Nutrition · Plant based alternative milks · Almond milk · Soy milk

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Abbreviations

DRI	Dietary Reference Intakes
EAR	Estimated Average Requirements
HDL	High-density lipoprotein
LDL	Low-density lipoprotein
MUFA	Monounsaturated fatty acids
PUFA	Polyunsaturated fatty acids
USDA	United States Department of Agriculture

Introduction

Cow's milk has been widely consumed around the world for hundreds of centuries and acts as an important source of protein. It also acts as a wholesome complete food providing all the major nutrients like fat, carbohydrates and proteins. Further, researchers have shown that the consumption of bovine milk can help the human body by providing wide range of host-defence proteins (Hettinga et al. 2011; van Neerven et al. 2012). This is because various beneficial anti-microbial effects are observed in both human and bovine milks. Especially in the case of infants, it was observed that the consumption of raw cow's milk has reduced the risk of fever and respiratory infections considerably (Loss et al. 2015). Despite the considerable advantages with the consumption of cow's milk there are various downsides associated with it. Firstly, the presence of various pathogens like *Salmonella* spp. and *Escherichia coli* O157:H7 in milk has been associated to cause wide spread disease outbreaks around the world (Oliver et al. 2009).

Secondly, the cow's milk allergy is one the most wide spread allergy among infants and children (Vanga et al. 2015c). According to the latest reports, 2.2–3.5% of the infants are allergic to cow's milk followed by peanuts and

tree nuts (Gray et al. 2014; Sicherer and Sampson 2014; Vanga et al. 2015a, b). But, recent studies conducted on a large scale have shown that about 35% of these infants out grow their allergenicity towards milk by the age of 5–6 years; and this may further increase to 80% by the time they reach 16 years (Gray et al. 2014; Santos et al. 2010; Skripak et al. 2007). Another issue widely associated with consumption of cow's milk is 'lactose intolerance'. The main source of lactose carbohydrate in humans are human milk and bovine milk (Scrimshaw and Murray 1988). The intolerance is due to the absence or deficiency of the enzyme lactase in the digestive tract and is widely observed in 15–75% of the adults (Bahna 2002; Scrimshaw and Murray 1988). Few studies showed that 80% of people from African origin and 100% people of Asian and American Indian origin are lactose intolerant (Swagerty Jr et al. 2002). Further, other factors like presence of cholesterol and vegetarianism have pushed the people and the food industry to look for alternatives. Few of the researchers have also found a relation between higher risks of cancer being associated with regular consumption of milk both in males and females (Qin et al. 2007; Song et al. 2013). Increasing demand for Vegetarian and Vegan diets all over the world with concern over health and environment are also a major contributing factors (Messina and Reed Mangels 2001; Van Winckel et al. 2011). Thus, the raise in the demand for alternatives to bovine milks has increased over the past few decades. These alternative milks also called 'non-dairy alternatives' mainly include soy milk, almond milk, rice milk, cashew milk and coconut milk. Various other sources have also been used to produce these milks, but relatively in minor quantities like hemp, hazelnuts, macadamia nuts, flax and oats. Commercial producers have also successfully introduced blended milks in the market successfully in countries like USA, Canada and UK.

Though, the consumption of bovine milk has been decreasing with a considerable increase in the alternative milks, the amount of research conducted is quite limited on these products with an exception of soy milk (Murugkar 2014, 2015; Stewart et al. 2013). This can be attributed to the fact that soy beans and various soy products have been used for centuries in many parts of the world. But various questions are still to be answered to find advantages to these plants based milk alternatives. Firstly, the ongoing debate on whether these products should be called 'milks' or 'beverage/juice/drink' should be addressed. The traditional definition of milk is "whitish fluid, rich in fat and protein, secreted by mammary glands of female mammals for the nourishment of their young, and taken from cows, sheep, etc., as an article of human diet" (Dictionary; Van Winckel et al. 2011). Though this definition does not fit the products that are currently sold as 'milk alternatives' in most cases their uses are similar to cow's milk and is used as an article for human diet. Further questions have been raised about the nutritional content and the health advantages of the plant based milks compared to the traditional milks which have to be answered through extensive research. It is only in the past decade that the researchers have tried to understand the importance of these products and their use in management of cow's milk allergy and intolerance and various other health issues (Sethi et al. 2016).

This review will try to answer these questions by compiling the nutritional aspects and various advantages and disadvantages of consuming plant based alternative milks in comparison to the bovine milk (Fig. 1). This review will help the readers in making an informed decision about introduction of plant based alternative milks in comparison to the traditional bovine milks. This will also aid the researchers in understanding the gaps in research regarding the milks and their health benefits in humans.

The nutritional content has been compiled by using commercial products and the nutritional data obtained from their packaging. The USDA web database has also been used as a source for the nutritional data which helped in cross referring this information depending on the availability of the database (USDA 2015). The data is presented in the format followed by Jaffe (Jaffé 2015). The data was accessed online on each of the organization's website which reported the nutritional content on bases of consumption quantities of 240 ml. A total of ten plant based milks were initially selected to be analysed. The lower threshold for analysis of the data was put as four i.e. unless there are four independent companies that produce the same kind of product, it will not be considered for further analysis. Only four of the ten initially selected met this requirement, almond milk, soy milk, rice milk and coconut milk. But, it should be noted that only three of the above milks have nutritional content mentioned in the USDA database as of 2015 with an exception of coconut milk. All the major nutrients have been reported for the above 4 plant based alternative milks: carbohydrates, fats, proteins, vitamins and minerals. Among the vitamins and minerals only the ones that are most often mentioned on the label have been selected. It should be further noted that the values of vitamins and minerals are presented as % values. The Dietary Reference Intakes (DRI) values used to calculate the vitamins and minerals from the % values have been obtained from the reports issued by the Food and Nutrition Board of Institute of Medicine, National Academy of science accessed through National Institutes of Health, US Department of Health and Human Services. The final DRI values used were calculated using the averages of recommended intakes for all the males and females from all ages which have been reported in Table 1.

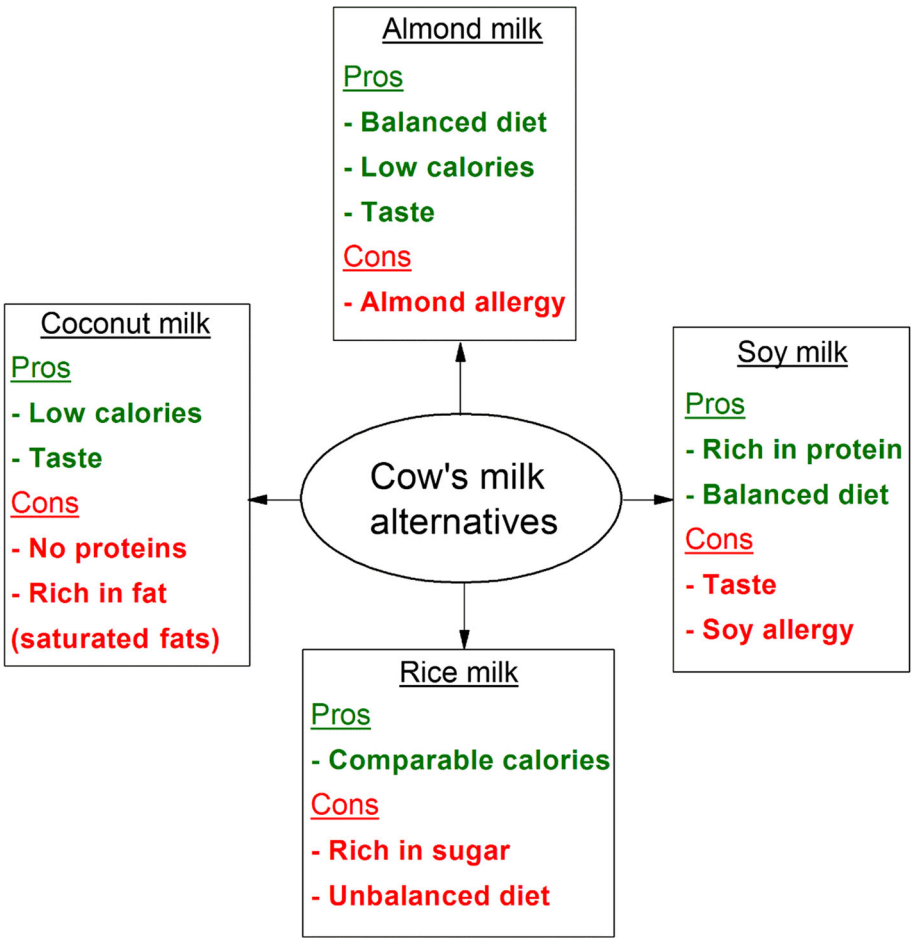

Fig. 1 Pros and Cons of plant-based milks

Analysis of plant based alternate milks

Almond milk

Traditionally, almond beverages have been consumed for a long time due to its flavor and taste. But, in recent years almond milk has become one of the most popular plant based alternative milks in North America, EU and Australian beverage markets (Dhakal et al. 2014). They were primarily introduced and marketed as an alternative milk beverage to the children and adults suffering from health conditions which include cow's milk allergy and lactose intolerance. Research conducted on almond milk suggests that the consumption of almond milk can be an effective solution in children suffering with allergy or intolerance against animal milk. In few cases, it was found to be even better than the generally followed alternatives like soy-based meals and protein hydrolysate formula (Cuppari et al. 2015; Salpietro et al. 2005). The various health benefits involved in consumption of almonds are also one of the key factors that helped boost the consumer demand for almond beverages. Almonds have a high content of monounsaturated fatty acids (MUFA) that are considered helpful in weight loss and weight management. There is also a considerable amount of compelling evidence that MUFA helps in reduction of low-density lipoprotein content in the body (Grundy 1986). Almonds also act as a vital source of various nutrients including proteins, fibre, vitamin E and manganese (Chen et al. 2006). Almond milk is a colloidal dispersion obtained after mixing water with powdered or pasted almonds. The general method of preparation involves soaking and grinding the almonds with excess of water. The milky white liquid is obtained after the solids are filtered (solid content depends on the nut and water ratio). In commercial processing, the milky white liquid is generally homogenized using high pressure and then pasteurized to increase the stability and shelf life (Bernat et al. 2014). Recent studies have also showed that the homogenization and heat treatment of almond milk can result in deviations within the physical properties of the product in terms of particle size and viscosity (Bernat et al. 2015). The nutrient profile of almond milks available in the market are tabulated (Table 2).

A total of 7 brands of unsweetened almond milk were considered in Table 2. Almond milk found to be having the least number of calories ranging from 30 to 50 kcal with

Table 1 Nutritional content of almonds, soybean, rice and coconut

Components	EAR	Almonds	Soybean	Rice	Coconut	Cow milk 100 g	240 ml
Carbohydrates (g)	130	21.55	30.16	81.68	15.23	4.65	11.5
Sugars		4.35	7.33	–	6.23	–	–
Fibers	35	12.5	9.3	2.8	9	0.0	0.0
Fats (g)	35	49.93	19.94	0.55	33.49	3.66	9.05
Saturated		3.8	2.88	0.11	29.67	2.28	5.64
MUFA		31.55	4.40	0.2	1.42	1.06	2.62
PUFA		12.33	11.25	0.2	0.37	0.14	0.35
Cholesterol (mg)		0	0	0	0	14	34.1
Proteins (g)	55	21.15	36.49	6.81	3.33	3.28	8.11
Minerals (mg)							
Calcium	1100	269	277	11	14	119	294.2
Iron	6.5	3.71	15.7	1.6	2.43	0.05	0.12
Magnesium	350	270	280	23	32	13	32
Phosphorus	600	481	704	71	113	93	230
Potassium	4700	733	1797	77	356	151	373
Sodium	1500	1	2	7	20	49	121
Zinc	9.4	3.12	4.89	1.2	1.1	0.38	0.94
Vitamins							
Vitamin C (mg)	75	0	6	0	3.3	1.5	3.7
Thiamine (mg)	1	0.20	0.87	0.18	0.07	0.04	0.1
Riboflavin (mg)	1.1	1.14	0.87	0.06	0.02	0.16	0.4
Niacin (mg)	11	3.62	1.62	2.15	0.54	0.08	0.2
Vitamin B6 (mg)	1.2	0.14	0.38	0.11	0.05	0.04	0.1
Folate, DFE (µg)	320	44	375	7	26	5	12.36
Vitamin B-12 (µg)	2	0	0	0	0	0.36	0.89
Vitamin A (µg)	600	0	1	0	0	33	82
Vitamin E (mg)	12	25.63	0.85	–	0.24	–	–
Vitamin D (µg)	10	0	0	0	0	–	–
Energy (kcal)		579	446	370	354	64	158

35 kcal being the median. The carbohydrates and proteins available in almond milk range from mere 0.25 to 3 g and 1 to 5 g respectively. Hence, the band can be chosen based on the requirements of carbohydrates and proteins. Calcium is another criterion that has to be evaluated for selecting a particular product and it ranges between 22 and 495 mg with 330 mg as the median. The higher quantities of calcium are due to the addition post processing to mimic the cow's milk calcium levels. Almonds also have a good levels of antioxidant vitamins and the same is reflected in the almond milk. Vitamin E ranges from 1.2 to 6 mg with mean and median values of 3.84 ± 2.15 mg and 3.6 mg respectively. This fulfills 10–50% of EAR in an average adult human. Vitamin A in almond milk ranges from 60 to 180 mg with mean and median values of 77.14 ± 45.35 mg and 60 mg respectively, fulfilling 10–30% of EAR.

Soy milk

Soy is a unique dietary source which is very rich in proteins and fat. These seeds contain up to 35–45% protein and 20% fat and act as an important source of protein especially in people following vegetarian diet (Friedman and Brandon 2001). They have been part of South Asian diet in various forms for thousands of years, whereas the human consumption in North America and parts of Europe has been limited to a century. Traditionally in South Asian countries, various soy products are consumed regularly which include Miso, tempeh and soybean paste (Barnes 1998). The cultivation of soybean in the Western countries only started in the early Nineteenth century. Since then USA turned out to be the largest soybean producer around the world, predominantly due to various research activities sponsored by United Stated Department of Agriculture (USDA). The soybean produced in the US is primarily used in

Table 2 Nutritional profile of almond milk

Components	EAR	Mean	SD	Median	Min	Max	N
Carbohydrates (g)	130	1.32	0.90	1	0.25	3	7
Sugars		0.11	0.28	0	0	0.75	7
Fibers	35	0.64	0.45	0.75	0	1	7
Fats (g)	35	2.71	0.48	2.5	2	3.5	7
Saturated		0	0	0	0	0	7
MUFA		1.67	0.29	1.5	1.5	2	3
PUFA		0.67	0.28	0.5	0.5	1	3
Cholesterol		0	0	0	0	0	7
Proteins (g)	55	1.67	1.63	1	1	5	6
Minerals (mg)							
Calcium	1100	325.29	193.55	330	22	495	7
Iron	6.5	0.18	0.13	0.13	0	0.39	7
Magnesium	350	21	9.9	17.5	14	35	4
Phosphorus	600	48	62.35	12	12	120	3
Potassium	4700	65	58.84	40	35	170	5
Sodium	1500	146.42	36.25	160	95	190	7
Zinc	9.4	0.56	0.46	0.66	0	0.94	4
Vitamins							
Vitamin C (mg)	75	0	0	0	0	0	7
Thiamine (mg)	1	–	–	–	–	–	0
Riboflavin (mg)	1.1	0.19	0.15	0.275	0.022	0.33	5
Niacin (mg)	11	–	–	–	–	–	0
Vitamin B6 (mg)	1.2	–	–	–	–	–	0
Folate, DFE (µg)	320	19.2	0	19.2	19.2	19.2	1
Vitamin B-12 (µg)	2	1	0	1	1	1	4
Vitamin A (µg)	600	77.14	45.35	60	60	180	7
Vitamin E (mg)	12	3.84	2.15	3.6	1.2	6	5
Vitamin D (µg)	10	2.32	0.88	2.5	0.45	3.3	7
Energy (kcal)		36.43	6.90	35	30	50	7

vegetable oil production. The other products that are produced include soy milk and tofu (Barnes 1998). Apart from the lactose intolerance, soy milk is also widely consumed for its health benefits primarily attributed to the presence of isoflavones (Example: daidzein and genistein) which are linked to exhibit anti-cancer properties (Jacobsen et al. 1998; Omoni and Aluko 2005). Soy milk was widely consumed as the alternative for cow's milk especially in the populations suffering from milk allergies and lactose intolerance. However, there has been a regular complaint among the consumers regarding the 'beany' flavor of soy milk. Further, presence of anti-nutritional factors in soybean and various soy products was also a concern (Harish Vagadia et al. 2016; Yuan et al. 2008). These factors contributed to the decline in its consumption as Almond milk raised in ranks to become more popular among the masses (Dhakal et al. 2014). In spite of the concerns regarding its consumption, it still is very widely consumed and is an important alternative source of protein in various cuisines and diets. The nutritional profile of commercial soy milk is outlined in Table 3.

Soy milk is widely consumed as an alternative milk and hence a huge number of local and national brands. Table 3 consists only the unsweetened and original soy milk products as seen in the case of almond milk. The total number of calories range from 80 to 120 kcal with a median value of 95 kcal. The number of carbohydrates range from 3 to 8 g with a mean and median value of 5 ± 1.83 g and 4 g respectively. Soy milk is an important source of proteins which ranges from 7 to 12 g with mean and median values of 8.71 ± 1.6 g and 8 g respectively which is the highest among all the alternate milk options available. Further, the fat in soy milk ranges between 2.5 and 6 g with a median and mean values of 4.5 g and 4.35 ± 1.14 g respectively. Due to the nutrient content, soy milk has been used as a substitute for cow's milk for over four decades. It is also seen that the total number of

Table 3 Nutritional profile of soy milk

Components	EAR	Mean	SD	Median	Min	Max	N
Carbohydrates (g)	130	5	1.83	4	3	8	7
Sugars		3.43	2.07	3	1	7	7
Fibers	35	0.96	0.82	1	0	2	7
Fats (g)	35	4.35	1.14	4.5	2.5	6	7
Saturated		0.64	0.38	0.5	0	1	7
MUFA		0.84	0.23	1	0.5	1	5
PUFA		2.4	0.65	2.5	1.5	3	5
Cholesterol		0	0	0	0	0	7
Proteins (g)	55	8.71	1.6	8	7	12	7
Minerals (mg)							
Calcium	1100	205.86	173.54	330	0	385	7
Iron	6.5	0.84	0.78	0.52	0.39	2.6	7
Magnesium	350	49	20.4	52.5	21	70	4
Phosphorus	600	108	40.25	90	60	150	5
Potassium	4700	364.29	66.3	360	250	460	7
Sodium	1500	65	43.49	60	5	135	7
Zinc	9.4	0.75	0.19	0.75	0.56	0.94	3
Vitamins							
Vitamin C (mg)	75	0	0	0	0	0	7
Thiamine (mg)	1	0.08	0.02	0.08	0.06	0.1	3
Riboflavin (mg)	1.1	0.24	0.12	0.28	0.07	0.33	4
Niacin (mg)	11	0.28	0.23	0.28	0.11	0.44	2
Vitamin B6 (mg)	1.2	0.096	0.024	0.096	0.072	0.12	3
Folate, DFE (µg)	320	33.6	20.37	33.6	19.2	48	2
Vitamin B-12 (µg)	2	0.68	0.38	0.7	0.3	1	4
Vitamin A (µg)	600	32.57	28.32	36	0	60	7
Vitamin E (mg)	12	4	–	4	4	4	1
Vitamin D (µg)	10	1.86	0.97	2.25	0.45	2.5	4
Energy (kcal)		95	15.16	95	80	120	6

calories available are comparable along with a balanced nutritional profile.

Rice milk

Rice milk is a variety of grain milk that can be prepared by mixing brown rice (generally milled) with water. Rice is always perceived as a rich carbohydrate source in diet and similarly it is observed that rice milk contains more sugar than the normal cow's milk. The processing leads to breakdown of carbohydrates into sugars which gives the rice milk its characteristic sweet taste without addition of sugars. This is achieved by the use of enzymes in few cases. Rice milk is lactose free making them prefect alternative for patients suffering from lactose intolerance (Lomer et al. 2008). Further, rice milk can also act as an alternative in the case of patients with the increasing allergy issues caused by soybean and almonds (Gizzarelli et al. 2006; Roux et al. 2003). Research has also showed that consumption of rice milk as an alternative to cow's milk without proper care can result in malnutrition, especially in the case of infants because of the varied difference in the nutrient profile (Katz et al. 2005; Massa et al. 2001). Kwashiorkor, a form of protein-energy malnutrition was observed in infants that were on a rice based vegan diet. Rice milks that are unfortified, especially that are home-made also lack in minerals and vitamins like calcium and B-12 unless fortified as in the case of most commercial milks (Craig 2009; Messina and Reed Mangels 2001). Further, study conducted by Shannon et al., showed that few rice milks in Mississippi, USA have total arsenic content to be 70% in excess to the WHO set levels for drinking water. Exposure to arsenic in long term can cause cancer and various other health complications (Shannon and Rodriguez 2014). Thus, these issues have to be addressed rapidly to protect the consumer's health. The nutritional profile of different brands of rice milks have been tabulated (Table 4).

Table 4 Nutritional profile of rice milk

Components	EAR	Mean	SD	Median	Min	Max	N
Carbohydrates (g)	130	25.28	1.7	26	23	27	5
Sugars		13.12	2.48	14	10	15.6	5
Fibers	35	0	0	0	0	0	5
Fats (g)	35	2.33	0.31	2.5	2	2.64	5
Saturated		0.16	0.22	0	0	0.48	5
MUFA		1.16	0.59	1.5	0.48	1.5	3
PUFA		0.83	0.75	0.5	0.3	1.68	3
Cholesterol		0	0	0	0	0	5
Proteins (g)	55	0.85	0.75	1	0	2	5
Minerals (mg)							
Calcium	1100	245.5	149.67	315	22	330	4
Iron	6.5	0.13	0.18	0.065	0	0.39	4
Magnesium	350	35	–	35	35	35	1
Phosphorus	600	63	38.19	63	36	90	2
Potassium	4700	50	–	50	50	50	1
Sodium	1500	72	22.53	65	45	100	5
Zinc	9.4	0.75	0.27	0.75	0.56	0.94	2
Vitamins							
Vitamin C (mg)	75	0	0	0	0	0	4
Thiamine (mg)	1	–	–	–	–	–	–
Riboflavin (mg)	1.1	0.3025	0.039	0.30	0.28	0.33	2
Niacin (mg)	11	–	–	–	–	–	–
Vitamin B6 (mg)	1.2	–	–	–	–	–	–
Folate, DFE (µg)	320	–	–	–	–	–	–
Vitamin B-12 (µg)	2	1	0	1	1	1	2
Vitamin A (µg)	600	67.5	61.85	60	0	150	4
Vitamin E (mg)	12	3	–	3	3	3	1
Vitamin D (µg)	10	2.09	1.48	2.5	0.45	3.33	3
Energy (kcal)		133	13.04	130	100	140	5

Rice milk is also widely consumed, but nutritionally it is very rich in carbohydrates ranging between 23 and 27 g with 26 g as the median. Proteins and fats are present in minute amounts.

Coconut milk

Coconut milk is the liquid that is extracted from the grated coconut white meat which is rich in saturated fats and it widely consumed in parts of Asia and South America. They are widely cultivated in the tropical climates as mentioned above and are exported as canned products to North America and Europe (Tinchan et al. 2015). It is one of the most widely used food ingredient in various authentic dishes that belong to the Indian-sub continent and South-east Asia (Eshtiaghi and Paoplook 2013; Marina and NurulAzizah 2014). But, coconut milks have been in focus of various researchers from 1960s due to their unique nutritional composition and properties. For example, Shantz and Steward (1952) and Pollard et al., (1961) analysed the various components present in coconut milks and their effect on growth cells (Pollard et al. 1961; Shantz and Steward 1952). Various researchers have also found conclusive evidence that consumption of coconut milk can increase the HDL (high-density lipoprotein) levels, which help in reducing the harmful LDL (low-density lipoprotein) (Ekanayaka et al. 2013; Mensink et al. 2003). Coconut fats have lauric acid which contributes mostly in raising the levels of HDL cholesterol that aids in reducing the LDL cholesterol levels in the blood stream (Ekanayaka et al. 2013). These health benefits associated with the consumption of coconut milk have also attributed to the increased demand in various countries. As mentioned earlier, due to their limited availability of coconuts they are mainly exported to the developed countries in North America and Europe in the form of canned products. Tinchan et al., analysed the changes in the thermally processed canned coconut milks (121 °C for 5 min) during storage. It was found that as the storage period crossed 2 months, the concentrations of short and medium chain

Table 5 Nutritional profile of coconut milk

Components	EAR	Mean	SD	Median	Min	Max	N
Carbohydrates (g)	130	1.19	0.56	1	0.75	2	4
Sugars		0.625	0.43	0.75	0	1	4
Fibers	35	0.25	0.5	0	0	1	4
Fats (g)	35	4.38	0.48	4.25	4	5	4
Saturated		4.13	0.63	4	3.5	5	4
MUFA		–	–	–	–	–	0
PUFA		–	–	–	–	–	0
Cholesterol		0	0	0	0	0	4
Proteins (g)	55	0	0	0	0	0	4
Minerals (mg)							
Calcium	1100	244.75	206.84	220	44	495	4
Iron	6.5	0.1	0.065	0.13	0	0.13	4
Magnesium	350	35	–	35	35	35	1
Phosphorus	600	–	–	–	–	–	–
Potassium	4700	46.67	11.55	40	40	60	3
Sodium	1500	63.75	64.21	52.5	0	150	4
Zinc	9.4	0.66	0.4	0.66	0.38	0.94	2
Vitamins							
Vitamin C (mg)	75	0	0	0	0	0	4
Thiamine (mg)	1	–	–	–	–	–	0
Riboflavin (mg)	1.1	–	–	–	–	–	0
Niacin (mg)	11	–	–	–	–	–	0
Vitamin B6 (mg)	1.2	–	–	–	–	–	0
Folate, DFE (µg)	320	19.2	0	19.2	19.2	19.2	1
Vitamin B-12 (µg)	2	0.75	0.29	0.75	0.5	1	4
Vitamin A (µg)	600	60	0	60	60	60	4
Vitamin E (mg)	12	–	–	–	–	–	0
Vitamin D (µg)	10	2.92	0.48	2.92	2.5	3.33	4
Energy (kcal)		48.75	7.5	45	45	60	4

fatty acids and other components like aldehydes increased due to lipid oxidation. Thus, increased storage time can result in reduced nutritional value of coconut milk (Tinchan et al. 2015). Table 5 outlines the nutritional profile of coconut milk products that are currently available in the market.

Coconut milk is completely unique compared to other milks discussed as the total number of calories is quite less ranging between 45 and 60 kcal with a median value of 45 kcal. But, majority of these calories come from saturated fats as it contains no proteins and as low as 0.75 g of carbohydrates compared to 4–5 g of fats.

Discussion

As already mentioned above, one of the primary reasons for the increased demand for plant based alternative milks is associated with lactose intolerance. This is the condition where patients are unable to digest the lactose sugar due to insufficient amount of lactase enzyme in the digestive tract (Swagerty Jr et al. 2002). The common symptoms reported on consumption of lactose products include bloating, abdominal pain, flatus and watery stool. In some cases, nausea and vomiting are also observed (Lomer et al. 2008). Irrespective of the large portion of population suffering from lactose intolerance, mammalian milk including cow's milk is widely consumed due to its nutritional content. The mammalian milk has perfect composition of nutrients because it acts as the only source of energy to the neonates of different mammalian species. For example, human milk is a perfect source of nutrition to a newborn infant (El-Agamy 2007). However, when the human milk is not available cow's milk is usually the substitute used for human consumption because of the nutritional similarities. The nutrient profile of cow's milk is provided in Table 1. Consumption of 100 g of cow's milk provides about 64 kcal of energy with 4.65 g of Carbohydrates giving 29% energy, 3.66 g of fat yielding 46% energy and 3.28 g of protein yielding 21% energy. To act as an alternative

source of milk, the selected food should have a similar energy distribution as shown above. This energy distribution is much more balanced compared to almonds, rice and coconuts which are used in the manufacturing of alternative milks. From Table 1 it can be calculated that 69 and 76% of the total energies of almonds and coconut come from fats and 89% of the total energy in rice comes from carbohydrates. Further, it has to be noted that the amount of saturated fat in coconut is very high which is generally associated with cardiovascular issues (Siri-Tarino et al. 2010). Rice is a very bad source of proteins and fat as starch is the main source of almost all of its energy. In the case of almonds and soybean, the content of mono-unsaturated fatty acids (MUFA) and poly-unsaturated fatty acids (PUFA) is significantly higher compared to saturated fats. Both, MUFA and PUFA were found to have beneficial health effects in controlling cardiovascular events and cancer formation (Kris-Etherton and Committee 1999; Tapiero et al. 2002; Tavazzi et al. 2008). Considering these advantages and the energy balance, soybean and almonds should be the ideal raw materials for milk preparation in replacing cow's milk in human diet in terms of the three major nutrients discussed. However, cow's milk is also a very important source of calcium which is required by the human body for the maintenance of bone health especially during childhood and adolescence (Bowman 2002; Sandler et al. 1985). Numerically, Table 1 shows that the total amount of calcium in 100 g of almonds and soybean is significantly higher than that of milk. But, this would be an improper way to compare these values as the total number of calories from 100 g of almonds and soybean is also significantly higher than that of milk. Hence to rectify this misleading nutritional information, a novel term is introduced 'weight of nutrient per kcal of energy' i.e. nutrient density for appropriate comparisons of the nutrient components with respect to the energy yield rather than the mass of the food (Newmark 1987). As per this criteria, milk (1.9 mg calcium/kcal) is found to be a much better source of calcium compared to almonds (0.46 mg calcium/kcal) and soybean (0.62 mg calcium/kcal).

Table 1 also shows the nutritional content of 240 ml of cow's milk compared with the values reported for plant based milk beverages. The calculation was done using the milk density reported as 1030 kg/m^3 (actual rage 1027–1033 kg/m^3) (Douglas 1995). The total energy yield of 240 ml of cow's milk was found to be 158 kcal, where as the average energy yield for the same amount of almond milk, soy milk, rice milk and coconut milk was calculated to be 36.43 ± 6.9, 95 ± 15.16, 133 ± 13.04, 48.75 ± 7.5 kcal respectively. The significantly lower number of calories present in plant based milk beverages is one of the biggest attractions for the increasing demand. The difference is due to the presence of sugars in cow's milk which is generally present in lower quantities in plant based milks (with an exception of rice milk). The total carbohydrate content in cow's milk is about 11.5 g in 240 ml. But in the case of plant based milk beverages, the total carbohydrate content was found to be 1.32 ± 0.9, 5 ± 1.83, 1.19 ± 0.56 g in almond milk, soy milk and coconut milk respectively. Conversely, rice milk has the highest quantity of carbohydrates with 25.28 ± 1.7 g which makes it comparable in terms of the total calories available on consumption of a similar volume. Cow's milk is a food obtained from mammal and hence there is a significant amount of cholesterol present (Jensen et al. 1991). None of the plant based milk beverages would have any cholesterol which is an added advantage and another contributing factor for increasing demand.

The fat content in cow's milk is about 9.05 g which gives a total energy of 72.4 kcal. Of the 9.05 g of fat in the 240 ml of cow's milk, about 63% (5.64 g) is saturated fat and 29% (2.62 g) is MUFA. All the plant based milks discussed have lower fat values compared to cow's milk. But, saturated fats are the lowest in almond milk (0%), followed by 7% in rice milk and 15% in soy milk. In the case of coconut milk, almost all (95%) of the fats reported is saturated. No data is reported regarding MUFA and PUFA. Almond milk with no saturated fats and high quantities of unsaturated fatty acids (86%) seems to be a better alternative among others considering fat as the criteria. Cow's milk is also a very important source of protein (8.11 g) in human diet and only soy milk is comparable in providing with same amount of proteins (8.71 g) to the human body. But, it should be noted that both cow's milk allergy and soybean allergy are major issues are associated with proteins present in these products which are primarily responsible for the eliciting allergic reactions (Sicherer 2011; Sicherer and Sampson 2010; Vanga et al. 2015c). Almond milk also provides a limited quantity of protein which is about 1.67 ± 1.63 g. Almond proteins are also responsible for causing allergic reactions in the allergic patients (Vanga and Raghavan 2016).

Calcium in most brands of the plant based alternative milks is added to mimic the levels present in cow's milk. The levels of calcium range widely between 22–495, 0–385, 22–330 and 44–495 mg in almond milk, soy milk, rice milk and coconut milk respectively. But, further research is needed to establish the consequences of added calcium in the human body. Various other minerals are available in considerable quantities in cow's milk which include magnesium (32 mg), phosphorous (230 mg) and potassium (373 mg). Most of the alternative milks contain comparable quantities of minerals i.e. at least 50–70%, with an exception of coconut milk with no phosphorous reported and lower amounts of potassium in rice milk and coconut milk. Few brands of soy milk were found to

contain even higher amounts of phosphorous and potassium compared to cow's milk. Cow's milk is also a very good source of vitamins. But, among alternative milks only soy milk contains comparable amounts of nutrients. The vitamin content of other milks is not reported on the labels meaning they are either not present or present in very minute quantities.

Conclusion

Overall, the review outlines the nutritional differences among various plant based alternative milks and cow's milk. It is quite clear that nutritionally soy milk is the best alternative for replacing cow's milk in human diet. But, various issues including the 'beany flavor' and presence of anti-nutrients are major hurdles which encouraged people to look for more alternatives like almond milk, etc., Though, almond milk also has a balanced nutrient profile and much better flavor, the nutrient density and the total number of calories are not as rich as that of cow's milk. Hence, when consuming almond milk care should be taken that various essential nutrients are available through other sources in the diet in appropriate quantities. Rice milk and coconut milk cannot act as an ideal alternative for cow's milk because of limited nutrient diversity, but they are the options for consumers that are allergic to soybeans and/or almonds. Further research is needed to understand the effect of various conventional and novel processing methods on the nutrient profile, flavor and texture of these alternative milks.

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Compliance with ethical standards

Conflict of interest The authors report no conflict of interest.

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