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# **Milk vs Plant Based Dairy Analogues: Myths and Facts**



**NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI**

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## Preface

Milk and milk products have been an integral part of human diet since ancient times and currently recognized as a functional foods due to increasing scientific evidences attributing to their health promoting and disease alleviating virtues. **'White revolution'** transformed the landscape of Indian agriculture, leading not only to self-sufficiency in milk production, but also improved socio-economic scenario across the nation. Dairying is considered as holistic and sustainable solution for livelihood, and nutritional security of India. Even in Sustainable Development Goal (SDG) 2030, dairying is directly related with 11 out of 17 action points. Recent Covid-19 pandemic has revitalized the immunomodulatory properties of milk nutrients.

In the recent past newer range of products termed as **'Vegan milk'**, based on extracts of different plants has been introduced in the market as substitutes for milk, advocating it as alternative to animal cruelty, for healthy life and environment friendly. These are also named as plant based dairy analogue or plant based milk such as soya milk, almond milk etc. However, the term **'Milk'** is well-defined in National and International standards across the globe. Codex Alimentarius Commission defines milk as **'the normal mammary secretion without either addition to it or extraction from it, intended for consumption as liquid milk or for further processing'**. The term **'Vegan Milk'** is a misnomer, and creates confusion among the consumers. Propagators of **'Plant Based Dairy Analogues'** often rate it superior than milk, although both significantly differ in chemical and nutritional compositions, sensory characteristics and other attributes. Another concern is the varied physiological response upon their consumption. Indian dairy sector is facing the adulteration by ad-mixing "plant based milk analogue" in Milk up to certain levels without being detected by human senses. However, the nomenclature of using the term "milk" to label plant-based beverages has sparked debates within the dairy industry due to confusion among consumers. There are certain other examples where the consumers have been cheated due to lack of awareness specially the difference between ice creams and frozen desserts where later include only vegetable fats/oils instead of milk fat in formulation. Several articles and reports have recently emerged without any concrete scientific investigations, linking consumption of milk and dairy products with a range of life-style-associated and other diseases and disorders. Such attempts to malign milk and milk products may seriously affect the impressive growth rate of Indian dairy sector which is considered as "life-line" of millions of resource poor farmers.

National Academy of Agricultural Science (NAAS) has attempted to bring stakeholders including academicians, researchers, policy formulators, industry personnel, progressive dairy farmers, traders, nutritionists and marketing professionals on one platform for deliberating on **'Milk vs Plant Based Dairy Analogues: Myths and Facts'** at DUVASU, Mathura on 10<sup>th</sup> December, 2022. I compliment the Convener of the brainstorming session Prof. Anil Kumar Srivastava for flagging off the issues and organizing the event. I am sure the policy document will serve as ready reference for policy makers.

April 2024  
New Delhi



(Himanshu Pathak)



# Milk vs Plant Based Dairy Analogues: Myths and Facts

## BACKGROUND

Milk and milk products have been an integral part of human diet since ancient times and have later gained prominence because of increasing scientific evidence pertaining to their health promoting and disease alleviating virtues. 'White revolution' transformed the landscape of Indian agriculture, leading not only to self-sufficiency in milk production, but also to improve the socio-economic scenario across the nation. Dairying is considered as holistic and sustainable solution for livelihood, and nutritional security of India. Although the Indian dairy sector is facing a multitude of challenges, its contribution for sustainability of Indian agricultural food production system will remain unrivalled. Milk, which is a complex mixture of a wide range of macro- and micro-nutrients, plays a significant role in human nutrition. Milk mining through advanced technological interventions has enabled to isolate the wide array of components present in milk. More than 500 milk macro- and micro- molecules that have one or the other role to play in health and nutrition have been identified. Recent developments in clinical sciences also contributed significantly in elucidating the mechanisms associated with therapeutic virtues of these molecules. Role of milk nutrients specially the minor milk proteins such as  $\beta$ -Lactoglobulin,  $\alpha$ -Lactalbumin and lactoferrin, in modulating the immune system is well-documented. (Egger and Menard, 2017) Milk, which is one of the most unique naturally occurring foods with balanced nutritional composition, has impeccable virtues of fat, protein, carbohydrates, minerals and vitamins, which is indeed a unique feature for any excellent particular food. Milk is most widely studied food and cow's milk is the most commonly consumed animal milk. It's a natural source of nutrients for calves and has been consumed by humans for centuries. Milk from other species including buffalo, goat, sheep etc. is also consumed by humans since ages. Consumption of milk is established to contribute significantly towards the overall growth and maintenance of the body system. (Tarver, 2019)

However, in the past decade, a new category has been added to this particular category of milk, although with much controversy and debate. This is the category of plant-based dairy analogues or commercially it is also called as Plant based milk substitutes. Whether the term 'milk' can be used with this category or not, itself is debatable and attracts attention of regulatory bodies round the globe. Very recently a new name of these plant-based milk substitutes or plant-based dairy analogues are given as '**Vegan milk**'. The term 'Vegan Milk' is again a misnomer, and creates confusion among the consumers. Promoters of '**Vegan Milk**' often try to draw an analogy with milk, although both significantly differ in chemical and nutritional compositions and their bioavailability, sensory characteristics and other attributes. These variations become more evident in terms of their pharmacological responses after their consumption. This paper is written to give the readers a clear idea of the major differences between milk and plant-based

milk substitutes or plant-based dairy analogues. The term 'milk' will be used in this policy paper only for representing the naturally occurring milk from animal origin. For its plant-based substitutes, the words like plant-based dairy analogues/ plant-based dairy substitutes/plant-based milk substitutes/plant-based beverages are used. In the dairy context, analogue is defined as "Products in which constituents are not derived from milk either in part or in whole of any milk constituents. The final products should resemble organoleptically and composition wise to milk or milk products. An analogue must not be nutritionally inferior to the products, it is to mimic.

Milk is nearly complete food for human growth and maintenance of the body system. However, certain limitations such as absence of iron, folate and the growing concerns over lactose intolerance in addition to its lesser availability in some particular geographical regions of world have given the impetus and push to the plant-based dairy analogues category. Of various plant-based milk substitutes or plant-based dairy analogues, the beverages of soya, almonds, oats, rice, coconut etc. are available in the market and newer plants are continuously being explored to manufacture the milk substitute out of them. Presence of various health promoting phytochemicals has been used as a marketing and promotion criteria for these plant-based milk substitutes. The changing preferences of customers and increasing number of vegan populations have also been ascribed as the boosting factors for the rapid surge of these plant-based milk substitutes in the market. There are pros and cons of consuming milk versus its counterpart plant-based dairy analogues. Industries for both the categories are putting their best efforts for their growth and development. Consumers are also getting more food choices to choose from selves of market. It's the responsibility of individual to assess the product, based on nutrition and make an informed choice rather than instinctively following the market trends.

## **SOURCES OF MILK VS PLANT-BASED DAIRY ANALOGUES**

Milk, the highly nutritious lacteal secretion (liquid food) is formed in mammary gland of mammals. It is designed by nature to provide all essential nutrients and therapeutic components and that too in desired amount and in best bioavailable form. In addition to cow and buffalo milk which are the most consumed type of milk, milk from many other non-bovine animals such as sheep, goat, camel, donkey, mare etc. is also gaining popularity owing to myriad of their unique features. Our country is endowed with great diversity of livestock and minor milk species including goat, sheep, and camel contributing about 4-5% milk in national milk pool. Non-bovine milk has attracted the attention of researchers, dairy industry and consumers because of unique nutritional profile and nutraceutical functions. Demand for non-bovine milk is continuously increasing considering their positive health benefits, which have also necessitated the technology development for novel products and ingredients from milk of these species.

Plant-based milk substitutes or plant-based dairy analogues are derived from various plant sources such as soy (the most common), almonds, oats, rice and coconut among others. They are made by these plant materials with suitable processing interventions and always fortified with vitamins and minerals trying to mimic the nutritional profile of natural milk.



## MARKET STATUS OF MILK- AND PLANT-BASED DAIRY ANALOGUES

Global milk production has witnessed significant and continual growth since past several decades. There has also been an incredible amount of creativity, technology and innovation in the way milk and milk products are consumed worldwide. By 2022, about 18% of global dairy market has been already captured by plant-based non-milk beverages. It has caused loss of about 10.1 billion US\$/year to global dairy industry. India is the largest producer of milk in the world. In year 2022-23, the milk production in India is reported to be more than 230 mton which was only 17 mton in 1950-51. The per capita availability of milk in India is 444 g/person/day as compared to global per capita availability of 229 g/person/day. The recommended per capita availability of Medical Council of India is 280 g/person/day (DAHDF2022-23). Presently India contributes about 23% of total world milk. In early 1970(s) the milk production in India was only 1/3<sup>rd</sup> of US and 1/8<sup>th</sup> of European Union. Today it is twice of US and at least 25-28 % more than European Union. In Indian agricultural food production system, milk is the largest agricultural food commodities. The value of milk is more than the total value of all grains and pulses put together (2019-2020). The value of milk was > 8 lakh crore as compared to 4.5 lakh crore of all grains + pulses.

The value of the global dairy market was reported to be 827.4 billion USD, which has increased to 893 billion U.S. dollars in 2022. And now the global dairy market is projected to grow to 1,243 billion dollars by 2028 (Statista, 2023). Majority of the milk produced globally is the cow milk followed by buffalo, goat and sheep.

The market of plant-based dairy substitutes/beverages or plant-based dairy analogues was estimated to be valued at USD 11.16 billion in 2018, which has grown to USD 19.67 billion by 2023 at a CAGR of 12% during the forecast period of 2018-2023. Further, the plant-based milk market is projected to reach \$47.55 billion by 2030 at the CAGR of 15% from 2023-2030. The data of Market Research revealed that global market growth of plant based dairy analogues is higher in USA, UK, Europe and Oceanic regions compared to other regions. In India the market of Plant based dairy analogues is growing fast with an estimated compound annual growth rate (CAGR) of 20.7% to reach US\$ 63.9 million by the end of 2024 (Strategic Market Research, 2023). Though, these plant based dairy analogue products do not meet the standards laid down for milk and other dairy products, prescribed by national and international food regulatory agencies. Further, these plant based dairy analogues also differ to a great extent among themselves in composition, nutrition and sensory evaluation. The global market of plant-based beverages has been primarily segmented into soy, almond, coconut and rice (Market and Market Reports, 2018). The demand for plant-based milk substitutes does not arise out of necessity, but rather out of the pursuit for more affordable and fancy food sources, even though the market is guided by specific choices and impacted by varied ideas acquired through time.

Considering the facts, it can be safely concluded that the market of plant-based dairy substitutes or dairy analogues is growing at a rapid rate. Still, it represents only a small share as compared to the well-established milk market.

## NUTRITIONAL COMPOSITION OF MILK AND PLANT-BASED DAIRY ANALOGUES

Milk is a wholesome complete food and it is like a “one-stop shop” for all important and for every single nutrient that body needs. The nutritional composition of milk is highly complex and milk is the most widely studied food. Bovine milk is consumed by the majority of global population. Milk is also an excellent source of “Nutrients of Concern”, which are under consumed by majority of population. These nutrients are Vit B<sub>12</sub>, Vit K, Ca and Vit D, which are generally not present in many common food. The “Milk Matrix” is best example to understand that how so many nutrients and bioactive molecules interact with each other with their physical food structure and pharmacological action, to produce the overall effect on health. (Bendtsen *et al.*, 2013)

Most of the plant-based milk substitutes are designed to mimic the composition of milk and efforts are made to bring them equivalent in composition. However, significant differences exist in the nutritional composition of milk and its plant-based substitutes as reported by Walsh and Gunn (2020). Nutritional compositions of these two categories are summarized in Table 1, highlighting the key differences. The major difference is that the plant-based milk substitutes have a higher water content and are always fortified with calcium and vitamins to improve their nutritional value, whereas milk is naturally endowed with calcium, protein and a wide array of micronutrients. Moreover, the composition of plant-based milk substitutes is highly variable and depends on the production protocol (depending on the brand recipe) and degree of fortification. Contrary to this, milk is relatively consistent in composition. Even if the composition of plant-based milk substitute is made equivalent to milk, the role of “Product Matrix/Food Matrix” should always be considered while assessing the nutritional value. Few important differences between milk and plant-based milk substitutes are summarised below.

### 1. Fats

- ◆ Generally, the whole milk is higher in energy and fat as compared to plant-based milk substitutes. Milk fats are termed as energy packed and weight reducing healthy fats. The Saturated fat content of cow milk is approximately 64% of the total fat, however most of the plant-based milk substitutes have very less fat content and hence for better comparison, they should be compared with the skimmed or semi-skimmed milk rather than whole cow milk. In contrast to trans-fat in processed food, the trans-fat which are naturally found in dairy products (also called as ruminant trans-fat) are considered always beneficial for health. Moreover, for preparing plant-based milk substitutes the saturated fat content varies as per the source of plant being used. It can also go as high as 95% in case of coconut milk. In general perception, milk fat has been wrongly picturized to have high saturated fat content, However, it should be emphasized that it contains more than 400 different types of fatty acids with varying proportions. Out of these, many fatty acids are bioactive and have strong impact on the human health. In addition, these fatty acids also play a vital role in contributing to the characteristic mouthfeel and texture to the milk products which is very hard to mimic in plant-based milk substitutes and their products. Further,

**Table 1.** Comparison of nutritive potential of cow milk with some of the commercially available plant-based milk substitutes

Type of milk	Carbo- hydrate (g/100g)	Protein (g/100g)	Fat (g/100g)	Energy (Kcal)	Ca (mg/100g)	K (mg/100g)	P (mg/100g)	Na (mg/100g)
Cow's milk	4.4	3.4	3.6	265.0	120.0	157.0	96.0	42.0
Soya milk	4.64 - 4.92	3.82 - 3.98	3.1 - 4.3	51.5 - 52.5	4.0 - 5.4	141.0 - 215.0	49 - 62.60	2.20 - 12.0
Almond milk	4.30-4.70	2.50 - 1.90	3.20 - 3.60	55 - 55.90	13.05 - 13.15	65.03 - 65.0	75.03 - 75.33	6.38 - 6.60
Coconut milk	3.75 - 9.41	0.59 - 2.00	4.12 - 6.00	50 - 92	176 - 178.1	631.0 - 639.02	240.0 - 256.35	36.00 - 38.36
Rice milk	9.41 - 12.70	0.28 - 1.26	0.97 - 1.11	47 - 112	118.0 - 121.35	26.34 - 27.00	55.91 - 56.86	39.20 - 40.59
Oat milk (Fresh)	27.30 - 50.01	9.70 - 17.30	5.20 - 12.40	576.6 - 607.1	84.30 - 85.60	669 - 671	672.30 - 816.32	3.11 - 3.21
Peanut milk (Fresh)	21.51 - 16.10	25.80 - 26.37	47.22 - 49.20	462.8 - 567.0	54.00 - 92.00	501 - 658	76.00 - 358.0	Not reported
Hemp milk	2.5 - 20.0	0.83 - 4.0	1.25 - 3.0	19.0 - 21.06	12.03 - 20.3	110 - 126	54.84 - 63.98	85.69 - 140.01

(Source: Paul *et al.*, 2019; Walsh & Gunn, 2020)

milk fat is a notable source of all fat soluble vitamins (Vit A, D, E, K), which are completely absent in plant based dairy substitutes.

- ◆ The Milk fat globule membrane (MFGM) is a complex and unique structure and is primarily composed of lipids and protein. It is source of multiple bioactive compounds such as phospholipids: Phosphatidylcholine (lecithin), Phosphatidylethanolamine (cephalin), phosphatidate, sphingomyelin etc., and glycolipids & glycoproteins. Mounting clinical evidences suggest that MFGM is essentially required in infants for structural and functional development and maturation of gut. Clinical trials in adult revealed that MFGM also support cardiovascular health by lowering cholesterol and triacylglycerol uptake and their level in blood, and also lowering the Blood Pressure. In infant, MFGM is also essentially required for shaping the gut microbiota for immunity development (Chen *et al.*, 2012)
- ◆ In an extensive study, it was reported that those who consumed full fat milk and dairy products, had less belly fat, less tissue inflammation and 62% lower risk of type-2 diabetes. In a review of 10 well planned studies, the full fat milk was linked to reduce the risk of heart stroke and other cardiac events. In Australia, 69% lower risk of cardiac disease has been reported with consumption of full fat milk (grass fed), may be because of high level of CLA, omega-3 fatty acids and Vit K<sub>2</sub>. Milk saturated fat raise the level of HDL (good cholesterol), and is very effective to prevent heart disease and stroke. The grass fed animals' milk is also very rich in Vit E and beta carotene which fights the oxidative stress. Further the short chain fatty acid butyric acid, present in milk fat promotes the multiplication of neurons, regulation of cell growth and also acts as anti-tumor. The important point is that milk fat is not consumed in isolation.
- ◆ Milk/Dairy food also contain protein, Ca, and many other nutrients, which modulate the effect of fat on health (Astrup 2014)

## 2. Proteins

- ◆ Milk is always higher in protein content except to the protein content of soya beverage/ soya milk substitute, which is almost equivalent. Cow milk contains nearly 6 times more protein to that present in almond, rice or coconut beverages. The comparison should not only be focused on protein content but also on the quality of proteins and amino acids. Milk which is the excellent source of quality proteins, contains all 9 essential amino acids in high proportion (Methionine, Lysine, Phenylalanine, Threonine, Tryptophan, Leucine, Isoleucine, Valine, Hindidine) necessary for body function. Milk whey proteins build, maintain and repair damaged muscle tissues very rapidly. It is most popular supplement among athletes. Consuming milk also corrects the Vitamin A deficiency in cereal based diet, as it provides proteins with wide range of Amino acids (in addition to 9 EAA).
- ◆ It has been found that branched-chain amino acids such as leucine, isoleucine and valine, which are in abundance in whey protein, is very effective to lower the risk of age-related muscle loss. It also provides fuel during exercise. Casein in milk helps in soothing the burning taste buds. It also has the ability to increase

the absorption of Ca, P and other minerals from GIT. Whey proteins have also been associated to decrease the BP and improve mood during period of stress

- ◆ Higher consumption of milk led to greater “whole body muscle mass”, “bone mass” and better physical performance in adults. In fact, proteins make up about 50% of bone volume and 1/3<sup>rd</sup> of bone mass.
- ◆ For providing desired quantity of amino acids to body, the protein must have good digestibility which is close to 100% for milk proteins. Recently, the most important protein quality indicator is found to be the digestible indispensable amino acid score (DIAAS) and the DIAAS for milk protein is 1.18 as compared to only 0.91 for soy proteins (highest among all plant-based beverages). It has also been reported that milk proteins are the proteins best suited for muscle synthesis and recovery after exercise. It should also be noted that many anti-nutritional compounds present in some plant-based beverages may also interfere in the digestion and absorption of proteins. (Bendsten *et al.*, 2013).

### 3. Carbohydrate

- ◆ The major carbohydrate present in milk is lactose which is a naturally occurring disaccharide. It is considered as a low glycemic index sugar. Glycemic index of cow milk is 47 and the comparative glycemic indices of soya milk, almond milk and rice milk are 48, 64 and 100, respectively. Many of the plant-based milk substitutes also contains added sugar which should also be taken into account for comparison. Therefore, the consumers choosing plant based dairy substitutes over milk should opt for unsweetened versions to cut down the intake of added sugars.

### 4. Micronutrients (Minerals and Vitamins)

- ◆ Other than the major macronutrients present in milk, there are also very significant differences between milk and plant-based beverages in terms of micronutrients. Calcium, iodine and vitamin B12 are some of the major micronutrients present abundantly in milk while the plant-based milk substitutes do not contain these, if not fortified.
- ◆ Cow milk contains approximately 120 mg calcium per 100 g milk. Plant-based dairy analogues/dairy substitutes can also be fortified to this equivalent calcium content. However, differences exist in the bioavailability of calcium in the human body. The naturally occurring calcium in milk is present in the form of colloidal calcium phosphate which remains in suspension with casein micelles. This form of calcium is efficiently released in the acidic conditions during gastric digestion and thus a better bioavailability of the milk’s calcium. Contrary to this, the calcium bioavailability of plant-based beverages depends on the type of salts used for fortification. Further the milk contains Ca, P and Vitamin D exactly in the same ratio, which is required for 100% bioavailability of calcium, which lack in plant-based beverages. As such more research is needed in this direction to establish the bioavailability of calcium from plant-based milk substitutes.

- ◆ Iodine is another important micronutrient required for normal cognitive functions and growth in children. Poor iodine intake during pregnancy has been reported as a major cause of low IQ in the children. Milk is naturally rich in iodine however, plant-based milk substitutes are not fortified with this micronutrient. Regular consumption of such plant-based products as a substitute of milk can lead to iodine deficiency. Similarly, vitamin B12 (cobalamin) is available only in animal products including milk. Plant-based milk substitutes do not contain vitamin B12 unless fortified. Due care should be taken by consumers while opting for plant-based milk substitutes over natural milk, particularly the vegan population that do not consume any animal derived food products/supplements.

## 5. Milk Nutrients as Precursor for Bioactive Components

Milk is house of hundreds and thousands of bioactive components, which are completely absent in Plant based beverages. Casein, lactose and milk lipids, the major milk nutrients, often serve as base materials for the production of metabolites having positive influence on physiological system and can be termed as nutraceuticals. Richness of milk protein particularly whey proteins, in Sulphur containing amino-acids like cysteine and methionine assist in enhancing the level of natural antioxidant i.e. glutathione. Likewise, abundance of branched chain amino-acids facilitates the effective energy balance during exercises. Milk proteins, both casein and whey, are good source of bioactive peptides, which can be defined as specific protein fragments (obtained by enzymatic hydrolysis on digestion, proteolysis by enzymes or food processing) that have a positive impact on human body functions or conditions. There are several bioactive peptides obtained from milk or dairy products, i.e. opioid, antihypertensive, antithrombotic, mineral-binding, antioxidative and immune enhancing peptides. Further, serotonin, a biomolecule, production is also mediated by milk protein amino-acids. Bioactive lipids mediated compounds including prostaglandin, leukotrienes and thromboxane are produced in requisite amounts. Galactose, the hydrolytic product of lactose is essential for the development of vital organs including retina and brain. GMP, a by-product present in cheese whey, modulates the bio-synthesis of cholecystokinin, the satiety hormone. Milk phospholipids have attracted the attention of researchers because of their effect on brain health. (Singh and Srivastava, 2011)

As has been established that besides being a rich source of essential amino acids, milk is also known to have a myriad of bioactive peptides formed during digestion or processing of milk to products, which have series of pharmacological & therapeutic effects. These bioactive peptides are effective as antihypertensive, antioxidative, antithrombotic, hypocholesterolemic, antiappetizing, antimicrobial, immunomodulatory and cytomodulatory. (Qian *et al.*, 1995; Cabello *et al.*, 2012; Egger and Menard, 2017; Maccone *et al.*, 2017).

## 6. Dairy Foods: An ideal vehicle for delivery of Probiotic

In addition, dairy food (fermented milk) and probiotics are proved to be a perfect combination and dairy food is an ideal probiotic delivery vehicle. Fermented milk is an excellent food matrix for optimal expression of probiotic functionality. Some important

genes encoding probiotic functions are induced only on exposure to milk fermentation. Further, milk also neutralizes gastric acid and has inherent properties to buffer acid in the stomach and increases the survival of probiotic strain in gut. Further, refrigerated storage of milk also provide the stability to probiotics and there is a consumer's positive perception about dairy microbes and dairy products (Grover *et al.*, 2012; Malik *et al.*, 2015)

## COMPARATIVE EVALUATION OF MILK & PLANT-BASED BEVERAGES (PBB)

The nutritional content of plant-based milk substitutes can vary depending on the type of plant used, the processing method, and any added ingredients. Plant-based milk alternatives differ from milk in terms of both their macronutrient and micronutrient composition. PBB generally has lower protein content compared to milk. The plant proteins are deficient in certain key essential amino-acids such as lysine, methionine, tryptophan and exhibit lower protein efficiency ratio (PER), biological value (BV) and protein digestibility corrected amino acid score (PDCAAS) than milk proteins. The fat content in plant-based milk alternatives can vary depending on the type of plant used. Some PBB, such as coconut milk, may contain higher fat content compared to milk. Others, like almond milk, tend to have lower fat content. The lipid profile of PBB differed greatly and dominated by unsaturated fatty acids which are prone to oxidation thus limiting the shelf-life of the PBB. Compared to milk, plant-based drinks contain lower amounts of phosphorus, potassium, calcium, zinc, sulfur, iodine, and chloride. A systematic market survey of 103 PBB products from 28 brands available in New Zealand supermarket revealed that due to large variations among the PBBs and with milk, these PBB should not be considered as nutritional substitute for milk. PBB and milk are not interchangeable in diet of infant, children, pregnant and lactating mothers because of lower nutritional value and nutrient density in PBB. Although PBB and dairy analogue may be of nutritional importance for the people who are unable (owing to dietary restrictions) or do not relish milk and dairy products or prefer low cost alternatives. Plant-based milk substitutes, such as almond or oat milk, generally lack naturally occurring vitamins A and D compared to milk. Moreover, the specific processing methods used in the production of plant-based milk substitutes can affect the heat labile vitamins. Anti-nutritional factors found in plant-based milk substitutes as trypsin inhibitor, phytic acid, and saponins can interfere with the absorption of certain nutrients, such as protein and minerals. Fermented plant-based milk manufacturing can be challenging due to the nutritional imbalance and flavor profiles of plant-based milk alternatives. In order to mimic, milk and milk products additive such as fat, stabilizers, emulsifier, minerals, vitamins, colour and flavouring are added in formulations, that's why these products are more of fabricated rather than natural. Milk mining through advanced technological interventions (separation technologies) has enabled us to isolate the wide array of components present in milk and more than 500 compounds have been identified so far. PBB are known to possess polyphenols, tannins, phytoestrogen, phytosterols, anthocyanins, carotenoids and several other phytochemicals. However, limited information is available on their exact concentration, processing mediated changes, possible putative functions, metabolism and possible safety issues. Polyphenols, carotenoids, tannins and anthocyanins are known for their anti-oxidative role including free radical scavenging and reactive oxygen species (ROS) inhibitors thus may check several degenerative diseases. Phytoestrogens of soy



and flaxseed used for PBB preparations have been proven to act as endocrine disrupters leading to certain health complications including reproductive malfunctioning, increasing incidences of cancers and obesity. Saponins, secondary metabolites present in soy and other plants serve as raw material for PBB is implicated with higher haemolytic activity, high toxicity and enhanced surface activity. Depending on their source and concentration, saponins may enhance or lower the free radical and ROS formation.

## ISSUES WITH PLANT-BASED DAIRY SUBSTITUTES

Plant-based milk alternatives are often marketed as nutritional replacements for bovine milk. Plant-based milk can be made from a wide variety of cereals, legumes, nuts, and seeds. The manufacturing process of various plant-based milks depends on the raw materials used. There are two main methods for processing plant-based milk: wet or dry. The wet process involves soaking and grinding the raw material in large volumes of water for up to 12 hours. The dry process involves milling the raw material into a flour or powder, which is then processed to separate the starch, protein, and fiber as desired, before being hydrated. In the case of plant-based milk substitutes, starch gelatinization can occur when the product is heated, leading to a thicker, more viscous consistency. Therefore, in order to obtain milk like consistency various processing aids are employed, which not only increase the price of the product but also alters the natural status of the beverage. For the preparation of few variants, enzymes are added to hydrolyse starches and reduce the viscosity, for example, in oat milk production. Enzymatic treatment is also required to maintain the non-dairy milk in the liquid state. Additionally, various emulsifying agents such as alginates, gelatin, xanthan gum, gum Arabic, locust bean gum, and gellan gum have been explored for their use in plant-based milk substitutes to improve emulsion stability mainly seed or nut based extracts. Plant-based milk substitutes lack certain key nutrients compared to milk, more particularly lactose and protein (Casein & whey proteins) and calcium. This can affect the growth and activity of LAB starter, amylolytic LAB as well as poor proteolytic activity during fermentation.

Beans and nuts which are utilized in preparation of plant based dairy alternatives may contain a number of anti-nutrients factors such as enzyme inhibitors, minerals chelators and even carcinogenic compounds. Moreover, altered lipid compositions in “Vegan Milks” not only limit their shelf-life but also generate number of free radicals and free-radical mediated ROS which have implicated in degenerative processes in body. All non-milk plant base beverages (PBBS) have added sweetness, sugar, artificial flavours, artificial colours, thickeners, salt and preservatives (highest amount of thickeners is in soya beverage). Another serious issue that is affecting Indian dairy sector is rising incidences of adulteration, as these so called “plant-based milk” are mixed easily up to certain levels without being noticed by human taste senses. There are certain classical examples where the consumers are being regularly cheated due to lack of awareness, including the difference between ice creams and frozen desserts, where later include only vegetable fats/oils instead of milk fat in formulation. Similarly, in certain pockets of the country the plant-based milk substitute are mixed with bovine milk to manufacture milk products like paneer, cheeses, fermented milk and even traditional dairy products. Since such products are available at cheaper price, it adversely affect the market of dairy products. Further, Several articles



and reports have recently emerged without any scientific evidence, linking consumption of milk and dairy products with a range of life-style-associated and other diseases and disorders. Such attempts to glorify these plant-based beverages at the expense of milk nutrients is seen as a deliberate attempt to jeopardise the efforts made by the dairy sector, which includes the small and landless dairy farmers at the grass root level.

## **OTHER IMPORTANT DISADVANTAGES OF SOME COMMONLY MARKETED PLANT-BASED DAIRY ANALOGUES**

Contrary to milk nutrients and bioactive compounds, the plant-based beverages are having several other disadvantages for human health. Some most important ones are indicated below (Liwei, 2003; Bingjing *et al.*, 1921; Singh, 2023):

### **Oat based dairy substitute**

- ◆ The process that turns oat into oat drink, transforms the complex starches into a simple sugar (maltose) which is a more refined carbohydrate and refined carbohydrates are worst for health than complex carbohydrates as they increase the level of sugar and insulin, both immediately
- ◆ In addition to this, it has high sugar (added & natural), canola oil and gluten.
- ◆ It provides very few nutrients than milk and that too are fortified.

### **Soya based dairy substitute**

- ◆ In soya beverage, apart from proteins and iron, all other nutrients are fortified. Falsely, consumers have become enamored by the taste of this non dairy drink.
- ◆ Soya has become most controversial food because of presence of phytoestrogen (isoflavones), which is similar to estrogen. This could produce the female infertility, cancer cell and thyroid malfunction. The Boiled soyabean has 90-130 mg of isoflavones/100 gm of soya.
- ◆ Soya is also a potential endocrine disrupter and it can mimic the estrogen action in body. It is reported to increase the risk of breast cancer.
- ◆ Soya is one of the eight most common allergen in both adult as well as children. The main types of protein in soyabeans are glycinin and conglycinin, which makes UP approximately 80% of the total protein contents. These two proteins trigger allergic reaction
- ◆ Here it is to mention that not only soya, but also Flax seed and dried fruits beverages have high content of (isoflavones)
- ◆ Soya has very high phytic acid contents, which chelates and hinder the absorption of many micronutrients from gastro intestinal tract.
- ◆ Soya protein also has trypsin inhibitor and lectin which causes adverse health effects. Lectin binds to the intestinal epithelium and cause GIT disturbance

## Almond and Cashew based dairy substitute

- ◆ It is very poorly concentrated source of beneficial nutrients, even found in whole almonds, including protein, fiber and healthy fats. In fact many brands contain only 2% almonds and cashew.
- ◆ These are often prepared by removing the skin of dry fruit, which further reduces the fiber, protein and many vitamins and minerals.
- ◆ It also contains phytic acid, which binds with Fe, Zinc and calcium & reduces their absorption and bioavailability.
- ◆ Cashew drink is again very poor in protein contents

## Coconut based dairy substitute

- ◆ It is of coconut taste, contain no protein, little to no carbohydrate, very high in saturated fat (a medium chain triglycerides)

- In general, all plant-based dairy analogues are very low in proteins except soya beverage. Further the quality of protein in these plant beverages is also very poor as compared to milk. Milk has 8 times more proteins as compared to beverages of rice, coconut, flax seeds and almonds, which also contain a long list of added unhealthy food and also many non-food ingredients.
- Further plant-based dairy substitutes are not a normal and natural source of many vitamins and minerals, which are naturally present in milk. These PBB(s) are attempted to mimic the milk nutrients by fortification, however this practice is not standardized. As per food regulation, food products are not permitted to contain many of the added minerals and vitamins. In addition the nutritional quality of all nutrients in PBBs is so poor that their use in infants can lead to very serious nutritional risk.
- On the other hand Milk is the best natural food full of nutrition and nutraceuticals and pharmacologically active molecules with proven health attributes.

## Physical stability and additives

The major macronutrients present in milk i.e., fat and protein are naturally in stable form. Milk fat is emulsified by a complex milk fat globule membrane and exists in globular form in milk. Milk proteins are also stable and possess a complicated structure of stable casein micelles formed in the mammary glands during post translational modifications. On the contrary, plant-based milk substitutes requires the addition of additives for achieving physical stability in the product. These additives include emulsifiers and stabilisers. In addition, flavouring ingredients, salt etc. are also added for better sensory attributes. Plant-based milk substitutes are the extracts from various parts of the plants and without

the addition of additives such as stabilizers, emulsifiers, thickeners etc., as such there is always problems of cloudiness and sedimentation in the products. Here it is very important to mention that emulsifiers, stabilizers, thickeners are having their own side effect on health and wellbeing of human.

## RECOMMENDATIONS

1. Plant based beverages (PBBs) should never be named as “milk” or even “milk substitute” or “milk analogues” or “Dairy analogue” as these can never mimic the “food matrix of milk” with fortification of nutrients. The definition of milk is very well defined. These misnomers are creating confusion in the mind of consumers.
2. Plant-based dairy analogue is endowed with several bioactive phytochemicals known for their adverse effect on human health
3. Ministry of Health and Family Welfare through its regulatory body i.e. Food Safety and Standard Authority of India (FSSAI) should develop a policy framework and guidelines to discourage and deal with people or groups creating and circulating false health and nutritional attributes of plant-based non-dairy beverages. Government must provide adequate fund support for validating the health claims and evaluating the possible toxicity of bioactive components present in food products through multidisciplinary teams.
4. No doubt product diversification is always good for consumers and industries, however, the promotion of plant-based beverages should not be done for the replacement of milk. Milk has been consumed by the infants and the adults since ages and the nutritional qualities inherent in milk is very difficult to simulate in other food.
5. Although Plant-based beverages can be made equivalent to milk in composition through fortification of nutrients, but the nutritional quality, digestibility and bioavailability of nutrients present in milk cannot be matched, because it is not only nutrients in milk but it is “Food matrix” of milk and this cannot be reproduced. Moreover, milk and milk products matrices are proven for their 100% efficacy for delivery of nutrients to the target site and thus offers better absorption in the human body.

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