

RESEARCH ARTICLE

PRODUCTION OF PLANT-BASED MILK FROM LOCAL ALMOND NUTS (*Terminalia catappa* L.) AND EVALUATION OF ITS SENSORY AND NUTRITIONAL PROPERTIES

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ABSTRACT

An experiment was conducted to investigate the possibility of making plant-based milk using Local Almond (*Terminalia catappa* L.) nuts. Harvested nuts were cleaned, shelled and, separated into two sets based on their maturity stage: well-ripened and mature-green. Local Almond nuts at both maturity stages were blanched and blended with water at a ratio of 1:2 (w/w), and two different plant-based milk samples were prepared as T1, from well-ripened and T2, from mature-green fruit kernels. The sensory evaluation of prepared kernel-based milk samples was conducted, occupying a panel of 30 semi-trained members using a five-point hedonic scale. The product's appearance, odour, flavour, mouthfeel, and overall acceptability were tested and analyzed using the Friedman test. The proximate composition of the prepared plant-based milk samples was determined in triplicates, and the energy content of the milk samples was estimated based on their nutritional values and was compared with those of Cow's milk. Data were analyzed using ANOVA procedures at a 5% significance level. Obtained sensory data revealed that among two milk samples, milk prepared from well-ripened Local Almond kernel (T1) was recorded as the best sample except for aroma for all organoleptic attributes. The proximate analysis found that the crude protein, crude fat and crude fiber content of both T1 and T2 Local Almond milk samples were higher than those of Cow's milk. Among the samples, the T1 showed the highest crude fat content ($13.30 \pm 0.01\%$), whereas T2 showed the highest crude protein content ($7.40 \pm 0.00\%$). Carbohydrate content of both T1 ($2.09 \pm 0.00\%$) and T2 ($1.20 \pm 0.00\%$) was less than that of cow's milk ($4.80 \pm 0.01\%$). The study suggests mixing milk extracted from mature green fruits and well-ripened fruit kernels to improve the final nutritional quality of Local Almond milk. This study reveals the requirement for further studies related to Local Almond kernel-based milk as a good source of plant-based milk and a potential substitute for Cow's milk.

Keywords: Local Almond, Nutritional value, Plant-based Milk, Proximate composition, Sensory evaluation

INTRODUCTION

The nutritional importance of oil seeds is increasing worldwide as they contain significant quantities of edible oils, proteins and minerals. With the ever-increasing population, there is a huge demand for studying the potential oil seeds which would provide the proteins, especially in developing countries, where animal source proteins are not sufficiently utilized. Currently, some of the most commonly used vegetable oils are sweet almonds, corn, peanut, soybean, etc. However,

the novel trend in research studies is to seek different oil types which may have various industrial applications in addition to their use only as vegetable oil. Tropical Almond (*Terminalia catappa*) which belongs to the Combratacea family, is one of those unexploited oil seeds (Maria and Victoria 2018) which is native to Sri Lanka, India, and some other Asian countries.

Tropical Almond which is grown in Sri Lanka, is called Local Almond (*Terminalia catappa* L.) and it is named "Kottamba" and "Kottan" by the Sri Lankan people is well-

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grown in lowland coastal areas of the country up to an elevation of around 300 m. This tree is mainly grown for beautification purposes or shade or as a fruit tree, not on a plantation scale (Weerasekara *et al.* 2012). Its seeds are edible and much similar in taste to the commercially grown sweet almonds (*Prunus amygdalus*) (Christian and Ukhun 2006). Plants produce fruits (Figure 1) from about three years of age. Usually, the nutritious, tasty seed kernels are eaten after removing the thick and fibrous shell. The fruit is known to have a medicinal value as it contains antioxidant, anticancer, anti-bacterial and anti-diabetic chemical compounds. *T. Catappia* L. fruit nuts have a very high nutritional value and are rich in carbohydrates, proteins, vitamins, and mineral salts (Christian and Ukhun 2006). However, in Sri Lanka, Local Almond is considered an underutilized crop. As this fruit has not been used to produce processed products, most Local Almond fruits are wasted during the fruiting season (Weerasekara *et al.* 2012).

There is some literature about the biological and phytochemical properties of this crop's tropical almond fruits, bark and leaves, majorly for medicinal purposes, but, studies on nutritional properties are very limited. Oliveira *et al.* (2000) investigated the composition and nutritional properties of different edible seeds of Local Almond at the mature stage. It was revealed that the oil content of Local Almond fruit was almost equal to that of oil seeds such as sunflower, rapeseed and peanut, whereas the protein content was higher than that of some legumes such as green gram, peanuts, chickpeas and lentils.

The rising demand for cow's milk has urged us to study its substitutes or alternative foods from animal and plant sources. In addition, plant-based milk is recognized as therapeutic food, as it can protect human beings from many non-communicable chronic diseases such as cardiovascular diseases and cancers, as plant-originated products are free from cholesterol and rich in unsaturated fatty acids. Moreover, they are a good source of several functional bioactive compounds such as antioxidants, flavonoids, phytosterols and vitamin E. Hence, the research on exploring potential plant-based

milk to replace Cow's milk would benefit consumers while obtaining high-quality proteins at a lower price.

In the European market, sweet almond kernels are widely used as a substitute for cow's milk, particularly for people suffering from lactose intolerance or with allergies to animal-source proteins and vegetarians (Maria and Victoria 2018). But in Sri Lanka, Sweet Almond is not grown due to climatic and economic restrictions prevailing in the country. According to the literature, it was found that no significant difference was seen in both the nutritional and sensory properties of Local Almond kernel and Sweet Almond nuts (Salawu *et al.* 2018). Hence, the Local Almond kernel can be considered an excellent substitute for Sweet Almonds, which would be used to produce milk and other value-added products in the Food Industry. Considering the rising share of people switching to plant-based milk products substituting cow's milk, there is a huge potential to develop milk utilizing tropical almond seed much similar to Sweet Almonds that are highly demanded and consumed worldwide.

Considering that Local Almond is an underutilized crop well-adapted to climatic conditions in Sri Lanka, this research was designed to develop a preparation process for Local Almond seed-based milk capable of utilizing it at a commercial scale. Further, analysis of nutritional and sensory properties of the processed *T. Catappia* L. based plant milk compared with the nutritional properties of cow's milk was aimed in this study.

MATERIALS AND METHODS

Experimental Location

The experiment was conducted at the Institute for Agro Technology and Rural Sciences, Hambantota (6.1429° N, 81.1212° E) from August 2021 to May 2022.

Collection of Local Almond (*Terminalia catappa* L) fruits

Adequate amounts of well-ripened Local Almond fruits were collected by hand picking from trees in the local areas of Hambantota

district, Sri Lanka. Green mature fruits were also collected from trees in similar locations.

Extraction of Plant Seeds

The collected fruits were cleaned and sorted to remove spoilt and infested ones. They were washed and shelled manually to extract seeds inside the fruits. Then the seeds were screened using the naked eye to separate and select good-quality seeds from infected seeds.



Figure 1: Fruits of Local Almond (*Terminalia catappa* L); mature-green fruits and well-ripen fruits

Preparation of Local Almond milk

The screened and selected seeds were separated into two sets depending on the maturity stage of kernels; well-ripened kernels and mature-green kernels (Figure 1), and weighed using an Electric balance (OHAUS – Navigator XL). Those two sets of kernels were used as the two treatments, T1: milk from well-ripened fruits, T2: milk from mature-green fruits. Both seeds were blanched using hot water. Then the blanched nuts were mixed with pure water at a 1:2 ratio on a weight basis and blended using an Electric Blender (SISIL Mixture Grinder- 4MXGR) at a medium speed. The blended mixture was strained using filter paper. All of the operations de-

scribed as mentioned above were carried out continually.

Sensory Evaluation

Sensory evaluation was conducted for the appearance, odour, flavour, mouth-feel and overall acceptability of prepared milk from Local Almond kernels by a panel of 30 semi-trained members using a five-point hedonic scale to select the treatment with best sensory appeal.

Analysis of Nutritional Properties

The milk samples prepared from both treatments were tested for proximate composition (moisture, crude protein, crude fat, total carbohydrates, total ash, and crude fibre) followed by standard methods. Cow's milk was used as a control, and all the samples were tested with three replicates for each.

Statistical Analysis

Data on proximate analyses were presented as a mean of triplicate analyses, and data were analysed using SAS statistical software. Median of sensory scores for each attribute was based on thirty judgments. The sensory properties of T1 and T2 were compared using the Friedman test – Minitab 19 statistical software. In both analysis, significant level was taken as 5%.

RESULTS AND DISCUSSION

Best treatment for the preparation of the Local Almond Kernel-based milk

The prepared Local Almond kernel-based milk was fluid with off-white colour, a nutty flavour and a creamy, smooth texture, and it was much more similar in sensory attributes to Cow's milk.

According to the Friedman test results, there was not any significant difference ($p > 0.05$) between T1 (milk from well-ripened Local Almond kernel) and T2 (milk from mature-green Local Almond kernel) with respect to appearance. The colour of both T1 and T2 was off-white, which was comparatively darker than Cow's milk. Both treatments have the same median value (3.50), although T1 has gained the highest sum of rank (47). That implies the selection of ripened or mature-green

seeds for developing the Local Almond milk has not significantly affected the appearance of the milk. In terms of aroma, there was a significant difference ($p < 0.05$) between the two treatments. T2 obtained the highest median value (4.0) and the highest sum of rank (50.0). The volatility of aromatic chemicals is the major factor that affects the aroma of foods. Some highly volatile chemical compounds give pleasant odours while some give off-odours. According to the results of the sensory evaluation, in terms of the aroma of the developed milk, a selection of mature-green fruits is preferred. Considering the flavour, there was a significant difference ($p < 0.05$) between the two treatments, but both treatments gained the same median value (4.00). But, well-ripened kernel-based Local Almond milk has gained the highest sum of rank (49.5). In terms of mouth feel and overall acceptability, there was no significant difference ($p > 0.05$) between the two treatments and both treatments gained the same median value of 3.50 and 4.0 respectively. That implies the selection of ripened or mature-green seeds for developing the Local Almond milk has not significantly affected the product's mouth feel and overall acceptability. But, T1 has gained the highest sum of ranks for the mouth feel (47.5) and overall acceptability (47.0).

Overall, the developed Local Almond-based milk had a satisfactory level of sensory acceptability. Referring to the highest sum of ranks for each sensory property obtained by

prepared milk samples, T1 has obtained higher values except for the product's aroma. Hence, it is evident that better sensory acceptability is recorded in the well-ripened kernel-based Local Almond milk. It is suggested to advance the study by incorporating different ratios of milk extracted from well-ripened and mature-green Local Almond fruit kernels would improve the sensory acceptability of the final product of Local Almond milk.

Proximate composition of Local Almond kernel-based milk

It was found that there was a significant difference between the two treatments, T1 and T2, on all the tested parameters (moisture, ash, crude protein, crude fat, crude fibre, and carbohydrates) of the milk (Table 2). Cow's milk showed the highest moisture content, $87.00 \pm 0.02\%$, compared to T1 and T2 milk samples. It was followed by T2, and the lowest moisture content, $78.06 \pm 0.01\%$, was recorded in T1. However, the T2 milk sample showed the significant ($p < 0.05$) highest crude protein content ($7.40 \pm 0.00\%$), and the Cow's milk showed the lowest, $3.40 \pm 0.00\%$. It proved that the milk based on mature-green Local Almond fruits is rich in proteins than the milk based on well-ripened Local Almond fruits and Cow's milk. Overall, both Local Almond-based milk treatments (T1 and T2) recorded a higher crude protein content than Cow's milk protein content. Ezeokonkwo and Dodson (2007) found that *T. catappa* seeds possess a very high crude protein content

Table 1: Friedman test results for Sensory evaluation of extracted Local Almond milk

Sensory property	Treatment 1 (T1: Local Almond milk from well-ripened fruits)	Treatment 2 (T2: Local Almond milk from mature-green fruits)	Highest sum of ranks	P - Value
Appearance	3.5	3.5	47 (T1)	0.285
Aroma	3.0	4.0	50 (T2)	0.033
Flavor	4.0	4.0	49.5 (T1)	0.003
Mouth feel	3.5	3.5	47.5 (T1)	0.132
Overall acceptability	4.0	4.0	47 (T1)	0.157

(25.81%) along with a good Essential Amino Acid (EAA) profile (16 g N/g): leucine (7.32), isoleucine (3.58), valine (2.74), phenylalanine (3.04), tryptophan (0.9), methionine (1.48), lysine (3.39), threonine (2.94), and histidine (2.96). However, Tyrosine (2.12) is found to be the limiting amino acid. In developing countries, protein malnutrition is highly observed along with the continuously increasing population and less animal-based protein consumption due to their high prices (Alozie and Udofia 2015). Hence, these findings reveal that there is a potential for milk from Local Almond fruits would become a better solution for people, more specifically, pregnant and lactating mothers, infants, and growing children to fulfill the daily dietary requirement of protein with a considerably lower cost. Further, Local Almond milk, being plant-based milk, becomes an ideal protein source for vegans and people suffering from Cow's Milk Protein Allergy (CMPA) (Muñoz-Furlong, 2003).

The highest crude fat content, $13.30 \pm 0.01\%$, was recorded in T1 (milk from well-ripened Local Almonds). Cow's milk showed the lowest crude fat content, $4.00 \pm 0.01\%$ Local Almond. Crude fat content is one of the essential nutritional aspects that would affect final milk quality. According to the Codex Alimentarius, the minimum requirement of fat % in milk should be 3% (Alozie and Udofia 2015). Both T1 and T2 milk samples have shown the fat content above 3%, which proves that Local Almond kernel-based milk contain a satisfactory level of quality in that particular aspect.

Further, it was revealed that the highest ash content (total minerals), $0.89 \pm 0.00\%$, was recorded in the T1. It was followed by Cow's milk, and the lowest was found in T2 ($0.70 \pm 0.00\%$). It suggests that Local Almond kernel based milk is rich in micronutrients. It is obvious that the mineral matter content in Local Almond milk is affected by the maturity level of selected fruits. It is required to investigate ions which include advanced analytical methods are required to measure the content of the different types of micronutrients available in Local Almond milk. Milk T1 showed the

highest value for crude fibre content, ($8.00 \pm 0.00\%$), and it was followed by T2. Comparatively, the Cow's milk did not show any fibre content. It revealed that milk produced from the Local Almond showed comparatively higher values of fiber.

Furthermore, Cow's milk had the highest carbohydrate content ($4.80 \pm 0.01\%$), followed by T1. The lowest carbohydrate value ($1.20 \pm 0.00\%$) was recorded in the milk prepared from the kernels of mature-green Local Almond fruits (T2). The present experiment indicated that milk produced from the T1 treatment and Cow's milk showed higher energy values, 151.07 ± 0.03 kcal/100 g and 150.00 ± 0.11 kcal/100 g, respectively than the energy estimated from the T2 milk sample. Referring to the nutritional properties of milk produced from Local Almond kernels (both well-ripened Local Almond and mature-green Local Almond), it was suggested that the nutritional quality of Local Almond kernel milk (Local Almond) could be improved by mixing milk from well-ripened kernels with mature-green kernels at different ratios and further nutritional analysis should be carried out.

Alozie and Udofia (2015) analyzed Sweet Almond milk and found that it contained 1.7% crude protein, 3.4% fat, 3.04% ash, and 4.5% carbohydrate. Accordingly, when Local Almond milk is compared with Sweet almond milk, a prevalent type of plant-based milk worldwide, it is well observed that the nutritional value of Local Almond milk is higher than that of Sweet almond milk. This proves that Local Almond milk is prospective plant-based milk that could be produced by countries, where Sweet Almond is not grown, as a food enriched with essential nutrients.

This study was basically conducted with the purpose of identifying the sensory acceptability of Local Almond kernel-based milk and evaluating its proximate composition. As the study revealed that the Local Almond kernel-based milk possesses satisfactory sensory acceptability and nutritional quality, further studies are required to evaluate the microbiological quality and to detect the shelf-life.

Table 2: Results of the Nutritional composition of milk prepared from Local Almond Kernel (Well-ripened and Mature-green Nuts) and the Cow's milk

Treatment	Moisture (%)	Ash content (%)	Crude protein (%)	Crude fat (%)	Crude Fiber (%)	Carbohydrate (%)	Energy (kcal/100 g)
T1	78.06±0.01 ^c	0.89±0.00 ^a	5.70±0.00 ^b	13.30±0.01 ^a	8.00±0.00 ^a	2.09±0.00 ^b	151.07±0.03 ^a
T2	78.90±0.00 ^b	0.70±0.00 ^c	7.40±0.00 ^a	1.80±0.00 ^b	6.89±0.00 ^b	1.20±0.00 ^c	141.33±0.06 ^b
Cow Milk	87.00±0.02 ^a	0.75±0.00 ^b	3.40±0.00 ^c	4.00±0.01 ^c	0.00±0.00 ^c	4.80±0.01 ^a	150.00±0.11 ^a
Significance	*	*	*	*	*	*	*

T1: Milk produced using well-ripened Local Almond fruits, T2: Milk produced using mature-green Local Almond fruits. Values denote mean±standard error of the three replicates. Means followed by the same superscripts in a same column are not significantly different at 0.05 probability level according to DMRT. ‘*’ and ‘ns’ represents significant at P<0.05 and not significant, respectively

CONCLUSIONS

This study concludes that the developed Local Almond kernel-based milk samples (T1 and T2) possess satisfied sensory acceptability. However, among the two different treatments, the best treatment was well-ripened kernel-based Local Almond milk. The study on proximate composition of milk samples concluded that, it was concluded that crude protein, crude fat content and fiber content of both Local Almond milk treatments (T1 and T2) were higher than those of Cow's milk. The crude fat percentage was highest in well-ripened kernel-based milk (T1), $13.30 \pm 0.01\%$, whereas the crude protein percentage was highest in mature-green kernel-based milk (T2), $7.40 \pm 0.00\%$. In contrast, the carbohydrate content of Local Almond milk was significantly ($p < 0.05$) less than that of the samples of Cow's milk. We found that a considerable amount of minerals was also available in Local Almond milk. The study concluded that the nutritional quality of Local Almond kernel-based milk could be further improved by mixing well-ripened and mature-green fruits in producing the milk. It was assumed that mixing could improve the nutritional quality even higher than that of Cow's milk. This study reveals the requirement for further research on producing Local Almond kernel-based milk as a good source of plant-based milk and a potential substitute for Cow's milk.

AUTHOR CONTRIBUTION

Chandimala UR conceptualized and designed the research study. Samarasinghe SPAK. carried out the experiment and analyzed the data under the supervision of Chandimala UR and Gunathilake DMCC. And, Chandimala UR wrote the article with input from all the authors.

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