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Proximate Composition of Spray-dried Sacha Inchi Milk Powder as Potential Plant-based Milk

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The recognition of sacha inchi (SI) as a superfood has shown its potential to be used as a new source of plant-based milk with high nutritional value. In this study, the SI milk powder was produced through the spray drying technique at two different inlet temperatures of 160°C and 180°C. The spray-dried SI milk powder was subjected to nutrient analysis using standard methods. The nutrients analyzed include ash, fat, moisture content, fiber, protein and carbohydrate. The water holding capacity was also measured for the SI milk powder to determine its ability to absorb water. The sensory evaluation was performed using a 5-point hedonic scale to rate panelist preference on the odor, color, and texture of the SI milk powder. Proximate analysis showed that spray-dried milk powder produced at 160°C inlet temperature has the highest value of nutrient content compared to the milk powder produced at 180°C. The nutrient content in milk powder produced at 160°C spray-dry inlet temperature was as follows: ash (6.98 ± 1.90%), fat (5.15 ± 0.21%), fiber (0.63 ± 0.13%), moisture content (2.94 ± 0.25%), protein (11.64 ± 0.08%), and carbohydrate (70.08 ± 0.48%). Meanwhile, nutrient content in milk powder produced at 180°C was: ash (4.44 ± 1.6935%), fat (4.03 ± 0.012%), fiber (0.56 ± 0.1294%), moisture content (5.56 ± 0.08%), protein (9.18 ± 0.44%), and carbohydrate (78.85 ± 0.50%). The water capacity of milk powder produced at the inlet temperature of 160°C was higher (93.97±3.11%) compared to the milk powder produced at 180°C (71.64 ± 1.23%) inlet temperature. The sensory evaluation test revealed that all the tested parameters, including odor, color, and texture, showed that the SI milk powder is acceptable as the new potential powdered milk. The study has shown that spray-dried SI milk powder is a good source of macronutrients and is feasible to be consumed as plant-based milk.

Keywords: Sacha inchi; plant-based milk; spray drying; proximate analysis

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Sacha inchi (*Plukenetia volubilis* L.), also known as inca peanut, is a plant from the *Euphorbiaceae* family originating from the Amazon forest. This plant grows at altitudes ranging from 200 to 1,500 m and is broadly farmed in Peru and Southern Colombia due to its high likelihood as an economic crop [1]. It can also be found in other parts of the world, such as South Africa and Southeast Asian countries.

These days, the prime use of sacha inchi (SI) nuts is mainly for oil extraction. The other possible uses of SI have not been exploited yet to their maximum extent. SI seeds have high nutritional values and are considered a "superfood" because they contain high-quality proteins, minerals, dietary fiber, and phenolic compounds, in addition to high polyunsaturated oil content [2]. The raw SI seeds have been reported to contain 24.2%–27.0% protein, whereas the SI flour contains 55.92% protein. The flour showed a high amount of essential amino acids of valine, leucine, isoleucine, threonine, and tryptophan compared to soybean meal [3]. These essential amino acids are very important and needed by the body through dietary intake. The proteins found in SI seeds exhibit favorable nutritional characteristics and hold potential for human consumption, particularly in the growing gluten-free product market.

Today, SI has been gradually recognized to have various advantages for human health and has been accepted as a food source due to its high nutritional value. According to [4], several studies have been conducted to assess the effect of consuming SI plant components, such as seeds, leaves, and shells, on human health. The consumption of this plant can help reduce blood pressure, inflammatory markers, and risks of cardiovascular disease [5]. Hence, there has been a surge in interest in developing the SI plant as a novel food in recent years. SI has the potential to be developed as a plant-based milk in the future. Plant-based milk is gaining recognition in the food market, as it is suitable for those with allergies and lactose

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intolerance. However, research available on the production of SI milk powder is still uncommon since many studies were only focused on the production of spray-dried SI oil.

This study was conducted to produce powdered milk using the spray drying technique, with beneficial nutritional values as a potential plant-based milk from locally planted SI seeds. The technique was used commercially for the drying of milk because the rapid time of heat contact and the high rate of evaporation give a high-quality product at a relatively low cost and suitable for heat-sensitive materials [6]. It is one of the most popular cost-effective drying technologies, utilizing controlled temperature, feed rate, and airflow to transform liquid to powder form [7]. Inlet temperatures between 120°C and 180°C were used to produce plant-based milk powder from rice, soy, oats, and almonds [8]. Thus, the selected 160°C and 180°C inlet and outlet temperatures and constant flow rate were used to produce SI milk powder.

The powdered milk preserves its nutritional properties and allows consumers to obtain a liquid milk product that is similar to fresh milk by reconstituting the milk powder with water [9]. Moreover, milk powder holds up to three times longer shelf life than liquid milk, produces less waste, and is more profitable. In addition, about 80% less volume is needed for storage and transportation when using powdered milk [10]. It enables manufacturers to control dosages and afterwards adjust to the preferences of the consumers.

In this study, a potential plant-based milk powder was produced using SI seeds using the spray drying method. The proximate composition of the milk powder, including ash, protein, moisture, fat and fiber, was determined and compared based on the different inlet temperatures during the spray drying process.

EXPERIMENTAL PROCEDURES

Preparation of Fresh Sacha Inchi (SI) Milk

SI seeds were collected from the Glasshouse and Nursery Complex, International Islamic University Malaysia (IIUM), Kuantan Campus. The shells and kernels of SI nuts were separated from the seeds. The seeds were cleaned and washed using clean tap water, followed by distilled water. The cleaned seeds were soaked in distilled water for 16 hours. Then, the strained seeds were processed using a blender at a ratio of 1:6 (mass:volume) of seeds to water (60℃) [11]. The slurry was filtered using a muslin cloth, and the milk was stored in a 500 mL Schott bottle prior to further analysis [12].

Preparation of Spray-dried SI Milk Powder

Maltodextrin (10% w/v) was mixed into the fresh SI milk and heated continuously at 30°C–50°C to produce a smooth lump-free maltodextrin-milk slurry, as reported by [13]. Then the mixture was poured into a lab-scale mini spray dryer (Buchi B-29) for the spray-drying process. The inlet air temperatures used were 160°C and 180°C, while the flow rate, aspiration, outlet air temperature, and feed flow of the spray dryer were set constant at 35 m^3/h, 100%, 100°C, and 51 mL/min, respectively. The milk powder was collected from the cyclone outlet of the spray drying machine and kept vacuumed at -20°C temperature until further analysis.

Proximate Analysis of SI Milk Powder

In this study, proximate analyses of powdered SI milk comprising moisture, protein, ash, fat and fiber content were determined using the standard methods. Spray-dried powder moisture contents were measured gravimetrically in a vacuum oven at 70°C for 8 hours [14] and conveyed as a percentage. The protein content was determined using the standard Kjeldahl method. The method of total fat content was determined based on the method of [15] with some modifications. The ash content was determined using the Soxhlet method with hexane as the solvent. Carbohydrate content was determined by calculating the remaining percentage from the total percentage of ash, moisture, protein, fat, and fiber.

Determination of Water Capacity Absorption (WAC)

Water capacity absorption (WAC) was determined according to the method by [16] with modifications. SI milk powder was dissolved in distilled water in centrifuge tubes and manually shaken for 30 seconds. The tubes were then left to rest for 10 minutes before being centrifuged for 25 minutes at 2300 rpm. The supernatant was decanted, and the tubes were dried in a conventional oven at 50℃ for 25 minutes in an inclined position at 15˚ to 20˚. Then, the tubes were weighed again, and the WAC was calculated using the following formula:

$$WAC = \frac{A - B}{Weight\ of\ original\ sample} \times 100\%$$

A : Original sample weight of powdered SI milk

B : Sample weight of powdered SI milk after oven drying

Sensory Evaluation Test

A total of 20 random panelists from IIUM, Kuantan Campus, comprising students (males and females), were involved in the sensory evaluation. The panelists were instructed to evaluate the 1 g of spray-dried milk powder produced at 160°C inlet temperature based on the scores given. The scores are based on the color, odor, and texture using the 5-point hedonic scale [17], as listed in Table 1.

Table 1. Hedonic scale for assessment of consumer acceptability of SI milk powder physical attributes.

Score	Physical attributes		
	Color	**Odor**	**Texture**
1	Dark	Dislike	Very lumpy
2	Slightly dark	Neither like	Lumpy
3	Moderate	Like slightly	Neutral
4	Pale	Like moderately	Smooth
5	Very pale	Like very much	Very smooth

RESULTS AND DISCUSSION

Proximate Composition of Spray-dried SI Milk Powder

The nutrient composition of the SI milk powder is presented in Table 2. Moisture content is detected higher in the SI milk powder produced at the inlet temperature of 160°C (5.56 ± 0.08%) compared to the inlet temperature of 180°C (2.94 ± 0.25%). This is similar to the 5% moisture in the United States Department of Agriculture Standards 2001 [18] and 5% moisture in the Codex Standards (207-1999) [19]. The moisture content decreased with the increase of the inlet air temperature due to an increase in heat transfer rate that helped more moisture removal [20]. The higher inflow of air temperature removes moisture from the product. The moisture concentration determines product quality and shelf life. Lowering the moisture content of the product helps retain flavor, aroma, and color for a longer period [21]. The low moisture content in powdered products will allow long storage stability.

The ash content of different types of spray-dried SI milk powder produced at different inlet temperatures ranged from 4.44 ± 1.69% to 6.98 ± 1.9%. As demonstrated by [22], the ash content of spray-dried infant milk formula powder ranged from 2.69% to 2.74%, which was lower compared to goat milk spray-dried powder (4.04%–6.12%). Based on the current finding, the highest ash content (6.98 ± 1.90%) is noted in SI milk powder spray-dried at an inlet temperature of 160°C, while the lowest ash content (4.44 ± 1.69 %) is found in SI milk powder spray-dried at an inlet temperature of 180°C. When the sample has a higher moisture content, the dry matter content, including ash, will be lower [23]. Therefore, the lowest inlet temperature produced a higher ash content, and this finding is consistent with previous findings [24]. The ash content in spray-dried SI milk powder processed at different inlet temperatures was not much different compared to other types of milk powder reported in other studies. According to [25], the ash content of cow's whole milk powder usually ranges between 6% and 7%. Nevertheless, no accurate comparison can be made due to the limited study on the ash content of SI milk powder and other types of plant-based milk powder. Ash content is the inorganic residue remaining after the complete oxidation of organic matter in food. The quantity of ash in a milk powder was calculated to determine its overall mineral content [26].

Fat content is higher in powdered SI milk produced at the inlet temperature of 160°C. The average percentage of fat content is 5.15 ± 0.21% when produced at the inlet temperature of 160°C, while the fat content for the inlet temperature of 180°C is 4.03 ± 0.01%. The inlet temperature has an impact on the fat content; as the inlet temperature increases, the fat content decreases. Higher inlet air temperatures generally lead to increased evaporation rates, which result in a higher concentration of fat in the powder. However, excessively high temperatures can cause thermal degradation of fats and other sensitive components [27], which is similar to the current findings. Similar results were observed in a study [28] on the production of oil palm milk powder by the spray-drying technique, where the fat content decreased from 25% to 10% as the inlet temperature increased. Likewise, a study reported that fat content was reduced as the temperature was increased from 200°C to 220°C [29]. A reasonable explanation would be due to the outer layer on the particle surface forming more quickly at higher inlet air temperatures, providing less time for the particles to shrink, which is anticipated to result in larger particles. More fat can be encapsulated by larger particles, lowering the surface free fat content.

The average fiber content for spray-dried SI milk powder at the inlet temperature of 160°C (0.63 ± 0.13%) is higher than the average fiber content of SI milk powder produced at the inlet temperature of 180°C (0.56 ± 0.13 %). Thus, as the spray-drying inlet temperature increases, the total fiber content of 1 g of SI milk powder decreases. High temperatures can cause thermal degradation of dietary fibers as well as leading to Maillard reactions, which can, directly and indirectly, affect the fiber content by altering the overall composition of the final product. It has been known that fiber is not present in cow's milk [30]. Fiber is only found in foods originating from plants, such as fruits, vegetables, grains, nuts, and legumes. This implies that the fluid generated by the mammary glands of mammals, such as meat, eggs, and milk, does not contain fiber [31]. This gives an advantage to SI milk powder as it contains fiber that can help in the digestive system.

Table 2. Nutritional content of spray-dried SI milk powder with different inlet temperatures.

Nutrient content (%)	Inlet temperature of spray dry	
	160ºC	180ºC
Ash	6.98 ± 1.90	4.44 ± 1.69
Fat	5.15 ± 0.21	4.03 ± 0.01
Fiber	0.63 ± 0.13	0.56 ± 0.13
Protein	11.64 ± 0.08	9.18 ± 0.44
Moisture content	5.56 ± 0.08	2.94 ± 0.25
Carbohydrate	70.08 ± 0.48	78.85 ± 0.50

The protein content of fresh SI milk is 15.076 ± 0.4379%, slightly higher than the protein content of SI milk powder spray-dried at the inlet temperatures of 160°C (11.64 ± 0.08%) and 180 °C (9.18 ± 0.44%). The differences could be due to the fresh SI milk that was not subjected to an intense thermal process, unlike spray-dried SI milk powder, which was produced at high temperatures. Consequently, less protein loss and degradation are observed in fresh SI milk, which leads to a higher protein content than in spray-dried SI milk powder. According to one study, air interface and temperature-related stresses cause a considerable amount of protein to become inactive or denatured. These forces cause irreparable damage to the protein secondary structures. Turning protein solutions into dry powder is an intricate procedure since proteins are sensitive to heat, especially while they are still in solution [32]. Additionally, protein denaturation, among other factors, occurred due to the disruption and destruction of protein secondary and tertiary structures during the spray-drying process at very high temperatures [33]. The result also illustrates a correlation between the nitrogen and protein contents of fresh SI milk and spray-dried SI milk powder. An increase in nitrogen content has a good impact on protein content. All organic nitrogen components are broken down in concentrated sulfuric acid in the standard Kjeldahl technique and converted into ammonium sulfate. Ammonia is produced under alkaline conditions and absorbed into a boric acid solution. The amount of nitrogen produced following the titration of the borate anions corresponds to the concentration of crude protein in the sample [34]. The protein composition of food samples increases with nitrogen content. It shows that the results for different inlet temperatures are significantly different, and different inlet temperatures of the spray-drying process of SI milk powder have a significant effect on the protein content of SI milk powder.

Water Absorption Capacity (WAC) of SI Milk Powder

WAC is used to describe a material's capacity to absorb water while being submerged in it. The outcomes of WAC of SI milk powder ranged from 70%–95% for different air inlet temperatures applied during milk spray drying (Table 3). It was found that the WAC of SI milk powder produced at 160°C and 180°C is 93.97 ± 3.11% and 71.64 ± 1.23%. The WAC decreases with the increase in inlet temperature. This finding is in accordance with the water absorption index of rice milk powder produced through the spray drying technique [20]. Since milk powders are intended for rehydration with water for consumption, the WAC of milk powder is an important parameter to measure the capacity of the powder to dissolve and absorb water. This corresponds to the results obtained, where at the inlet temperature of 160°C, more water was absorbed and dissolved than at 180°C. A few factors may have influenced how a powdered product reacts with water and the ability to absorb water. The moisture content and powder composition have the most effects on the absorption process. The angle of contact between the powder particles and water is crucial in this situation. WAC is determined by the chemical makeup of milk proteins (solution, suspension, or dispersion). The water is then taken up and held by a three-dimensional network that forms due to physical and chemical interactions. Since different temperatures were applied during the spray-drying process, the protein content of SI milk powder also varies, indicating that powder with high protein content, i.e., at the 160°C temperature, can absorb more water compared to the other sample.

Table 3. Water absorption capacity of spray-dried milk powder produced at different inlet temperatures.

Inlet temperature	WAC (%)
180ºC	71.64 ± 1.23
160ºC	93.97 ± 3.11

Table 4. Sensory evaluation of SI milk powder.

Sensory Quality	5-point Hedonic Score
Color	4.75
Odor	4.70
Texture	4.90

Sensory Evaluation

The SI milk powder was evaluated based on its physical attributes: color, odor, and texture, as presented in Table 4. The color of SI milk powder yields a mean score of 4.75, indicating a pale color as per the hedonic scale. The odor of SI milk powder exhibits a mean score of 4.70, signifying that most panelists moderately like the odor of the milk powder. The powder was also described as smelling slightly nutty. These findings indicate that roasting SI nuts and the spray-drying process helped to reduce the nutty odor of the powdered milk. Meanwhile, the mean score for the milk powder texture was recorded at 4.90, indicating that the SI milk powder has an acceptable texture. The spray-dried SI milk powder has high acceptability, as scored by the panelists, based on the overall score from the 5-point hedonic scale.

CONCLUSION

As a conclusion, the effect of inlet temperature on the nutrient content and sensory evaluation on the physical properties of spray-dried SI milk powder was investigated and observed. Based on the results, the most suitable inlet temperature to produce SI milk powder with a high value of nutrients is 160°C. Furthermore, it was found that as the inlet temperature of spray-drying increases, the nutrient content of SI milk powder decreases due to thermal degradation of the nutrient content during the process. On the contrary, the water absorption capacity of powdered SI milk increased as the inlet temperature during spray drying decreased. However, according to the statistical analysis, the effect of inlet temperature on the nutrients of SI milk powder varies significantly. As for the sensorial evaluation, most panelists accepted the odor, texture, and color of the milk powder. Hence, the current study on the production of spray-dried SI milk powder may serve to promote the utilization of SI as a plant-based milk alternative in the future.

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REFERENCES

1. Kim, D. -S & Joo, N. (2019) Nutritional composition of Sacha inchi (*Plukenetia volubilis* L.) as affected by different cooking methods. *International Journal of Food Properties*, **22(1)**, 1235–1241.

2. Sánchez, E. G. T., Hernández-Ledesma, B. & Gutiérrez, L. -P. (2021) Sacha inchi oil press-cake: physicochemical characteristics, food-related applications and biological activity. *Food Reviews International*, **39**, 148–159.

3. Gonzales, G. F., Tello, J., Zevallos-Concha, A., Baquerizo, L., Caballero, L. (2018) Nitrogen balance after a single oral consumption of sacha inchi (*Plukenetia volúbilis* L.) protein compared to soy protein: a randomized study in humans. *Toxicol Mech Methods*, **28 (2)**, 140–147.

4. Cárdenas, D. M., Gómez Rave, L. J. and Soto, J. A. (2021) Biological activity of Sacha inchi (*Plukenetia volubilis* Linneo) and potential uses in human health: a review. *Food Technology and Biotechnology*, **59(3)**, 253–266.

5. Castro, J. P., Vaca, C., Soto, E. J., Vargas, J. R., García, G., Banon, J. and Neira, E. F. and Tuesta, T. (2020) Sacha inchi oil (*Plukenetia volubilis*) stabilized with antioxidants for addition in fresh cheese. *African Journal of Food, Agriculture, Nutrition and Development*, **20**, 16638–16651.

6. Liu, K. S. (1997) Soybeans: Chemistry, Technology, and Utilization. *Chapman and Hall, New York*, 465–480.

7. Singh, P., Bilyeu, L. and Krishnaswamy, K. (2022) Spray drying process optimization: drought resistant variety (W82) soymilk powder using response surface methodology (RSM). *LWT-Food Science and Technology*, **166**, 113760.

8. Samborska, K., Budziak-Wieczorek, I., Matwijczuk, A., Witrowa-Rajchert, D., Gagos, M., Galdyszewska, B., Karcz, D., Rybak, K., Jaskulski, M., Baranska, A. and Jedlinska, A. (2024) Powdered plant beverages obtained by spray-drying without carrier addition-physicochemical and chemometric studies. *Scientific Reports*, **14**, 4488.

9. Olagunju, A., Muhammad, A., Aliyu, S., Mada, S. B., Isah, R., Abdullahi, S. A. and Audu, Z. O. (2013) Nutritional Values of Powdered Milk Commercially Consumed in West Africa. *International Journal of Food Nutrition and Safety*, **4(2)**, 55–61.

10. Augustin, M. A. and Margetts, C. L. (2003) Powdered Milk: Milk Powders in the Marketplace. In ed. Encyclopedia of Food Sciences and Nutrition (Second Edition). *Academic Press, Victoria Australia*, 4694–4702.

11. Tamuno, E. N. J. and Monday, A. O. (2019) Physicochemical, mineral and sensory characteristics of cashew nut milk. *International Journal of Food Science and Biotechnology*, **4(1)**, 1–6.

12. Aysu, Ş., Akıl, F., Çevik, E., Kılıç, M. E. and İlyasoğlu, H. (2020) Development of homemade hazelnut milk-based beverage. *Journal of Culinary Science &Technology*, **20(5)**, 421-429.

13. Sukri, N., Hashib, S. A., Hasfalina, C. M. and Abdulsalam, M. (2018) Effect of 40 maltodextrin concentration and slurry temperature on pineapple powder using ultrasonic spray dryer. *Food Research*, **2(6)**, 582–586.

14. Association of Official Agricultural Chemists (2005) Official method of Analysis, 18th Edition, Association of Officiating Analytical Chemists, Washington DC, Method 911.43.

15. Yadav, P. B., Edukondalu, L., Patel, S. and Rao, D. B. (2018) Influence of spray drying technology on the proximate composition of peanut (*Arachis hypogaea* L.) milk powder. *Journal of Pharmacognosy and Phytochemistry*, **7(5)**, 2852–2855.

16. Sosulski, F., Humbert, E. S., Bui, K. and Jones, J. D. (1976) Functional properties of rapeseed flours, concentrates and isolate. *Journal of Food science*, **41(6)**, 1349–1352.

17. Sanful, R. E. (2009) Production and sensory evaluation of tigernut beverages. *Pakistan Journal of Nutrition*, **8(5)**, 688–690.

18. United State Department of Agriculture (2001) Fundamentals of Dairy Science Powder Milk: USA Standards of Powder Milk. *2nd ed., FDSPM, New York*.

19. Codex Alimentarius (1999) Food Agriculture Organization/World Health Organization of Food Standards: Codex standards for milk powders and cream powders. *Codex Standard*, **207**.

20. Padma, M., Rao, P. V. K. J., Edukondalu, L., Aparna, K. and Babu, G. R. (2022) The effects of spray drying conditions on water absorption index, water solubility index, solubility, and water activity (aw) of rice milk powder. *International Journal of Environment and Climate Change*, **12(11)**, 517–529.

21. Angel, P. and Gurumoorthi, P. (2024) Optimization of spray drying process parameters for the production of cranberry flavored oat milk powder using response surface methodology. *Food Science and Technology*, **12**, 48–61.

22. Masum, A. K. M., Chandrapala, J., Adhikari, B., Huppertz, T. and Zisu, B. (2019) Effect of lactose-to-maltodextrin ratio on emulsion stability and physicochemical properties of spray-dried infant milk formula powders. *Journal of Food Engineering*, **254**, 34–41.

23. Czaja, T., Aldona, S. and Roman, S. (2020) Quantification of Ash and Moisture in Wheat Flour by Raman Spectroscopy. *Foods*, **9(3)**, 280.

24. Perring, L. and Tschopp, A. (2019) Determination of ash content of milk-based powders by energy dispersive x-ray fluorescence. *Microchemical Journal*, **145**, 162–167.

25. Tamime, A. Y. (2009) Dried milk products. In ed: Dairy powders and concentrated products. *Wiley-Blackwell. United Kingdom*, 180–234.

26. Lawal, N. S., Tajuddeen, N. and Garba, B. B. (2014) Assessment of some mineral elements in different brands of powdered milk sold in Samaru Zaria, Nigeria. *International Food Research Journal*, **22(6)**, 2634–2636.

27. Ogolla, J. A., Kulig, B., Bădulescu, L., Okoth, M. W., Esper, G., Breitenbach, J., Hendel, O. and Strum, B. (2019) Influence of inlet drying air temperature and milk flow rate on the physical,

optical and thermal properties of spray-dried camel milk powders. *Food Bioprocess Technolology*, **12**, 751–768.

28. Zainatul, A. S. and Anis, Z. (2020) Production of oil palm milk powder by spray drying technique. *Materials Today: Proceedings*, **31(1)**, 306–312.

29. Park, C. W., Bastian, E., Farkas, B. and Drake, M. A. (2014) The effect of feed solids concentration and inlet temperature on the flavor of spray-dried whey protein concentrate. *Journal of Food Science*, **79**, 19–24.

30. Antunes, I. C., Bexiga, R., Pinto, C., Roseiro, L. C. and Quaresma, M. A. G. (2022) Cow's milk in human nutrition and the emergence of plant-based milk alternatives. *Foods*, **12(1)**, 99.

31. Aydar, E. F., Sena Tutuncua, S. and Ozcelik, B. (2020) Plant-based milk substitutes: bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. *Journal of Functional Foods*, **70**, 103975.

32. Haque, M. A. and Adhikari, B. (2015) Drying and denaturation of proteins in spray drying process. *Handbook of Industrial Drying*, 971–984.

33. Nor, R. A., Harisun, Y., Ismail, W., Husnul, H. S., Fitrien, H. and Iylia, A. M. Z. (2020) Thermal effect of spray drying process on the quality of *Ficus deltoidea* extract. *Malaysian Journal of Medicine and Health Sciences*, **16(SUPP11)**, 95–100.

34. Jiang, B., Tsao, R., Li, Y. and Miao, M. (2014) Food safety: food analysis technologies/techniques. *Encyclopedia of Agriculture and Food Systems*, 273–288.