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EFFECTS OF PROCESSING PARAMETERS ON THE QUALITY AND PROPERTIES OF MANGO KERNEL FLOUR: A MINI-REVIEW

(Kesan Pemprosesan Parameter Terhadap Kualiti dan Sifat Tepung Biji Mango: Ulasan Mini)

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Abstract

Mango (*Mangifera indica* Linn) is a popular tropical fruits that is widely available in the market. In order to reduce food waste, mango kernels are usually treated as waste mango kernel flour due to their nutritional composition and bioactive compounds. However, the processing method used during the production of mango kernel flour has lowered its nutritional value and affected the quality of the mango kernel flour. In addition, the anti-nutritional found in the mango kernel influences the flour's quality. Hence, this review provides an overview of the effect of processing parameters on the quality of mango kernel flour (in terms of nutritional, functional properties, and bioactive compounds) and the application of mango kernel flour in baking products. The findings proposed that the soaking, blanching, and drying processes have an impact on the nutritional value, functional properties, and bioactive compounds of mango kernel flour. Further investigation into optimising processing parameters is required to obtain high-quality mango kernel flour.

Keywords: mango kernel flour, soaking, blanching, nutritional composition, anti-nutrient

Abstrak

Mangga (*Mangifera indica* Linn) merupakan salah satu buah tropika yang terkenal di pasaran. Bagi mengurangkan sisa biji manga, biji mangga biasanya diproses menjadi tepung biji mangga kerana komposisi nutrisi dan sebatian bioaktifnya. Bagaimanapun, kaedah pemprosesan semasa penghasilan tepung biji manga telah mengurangkan nilai nutrisi dan mempengaruhi kualiti tepung biji mangga. Selain itu, anti-nutrien yang terdapat di dalam biji mangga juga mempengaruhi kualiti tepung. Oleh itu, ulasan ini memberikan gambaran keseluruhan kesan parameter pemprosesan ke atas kualiti tepung biji mangga (dari segi komposisi nutrisi, sifat fungsi dan sebatian bioaktif) dan penggunaan tepung biji mangga dalam produk bakeri. Hasil kajian menunjukkan bahawa proses rendaman, penceluran dan pengeringan adalah faktor yang mempengaruhi nilai nutrisi, sifat berfungsi dan sebatian bioaktif dalam tepung biji mangga. Siasatan lanjut keatas pengoptimuman parameter pemprosesan diperlukan bagi mendapatkan tepung biji mangga yang berkualiti tinggi.

Kata kunci: tepung biji mangga, rendaman, blanching, komposisi nutrisi, anti-nutrien

Introduction

Mangifera indica Linn, or commonly known as mango, belongs to the family of Anacardiaceae. Mango is well grown in the tropical and subtropical regions [1]. The production of mango throughout the year is about 42 million tonnes [2], and it is considered the second most traded fruit globally after bananas [3]. Countries that largely produce mangoes are India, Mexico, Thailand, China, and Indonesia [4]. Among these countries, India is the largest producer of mango [5], whereas Mexico is the largest exporter of mango, as it exports about 287,771 tonnes per annum [6]. Generally, mangoes are rich in dietary fibre, carbohydrates, fats, protein, phenolic compounds and provide high energy. Those nutrients found are crucial for the growth development and health of well-being [7]. Besides that, mango is also known as a super fruit due to its functionality as a food and an ingredient in new food product development [8]. Since mango is one of the most widely produced tropical fruits in the world, the waste generated from its processing is massive. It is estimated that about 35% to 60% [6] of mango by-products such as seeds and kernels have been discarded as waste [9], subsequently causing environmental pollution. In line with the concept of waste to wealth, mango kernels (Figure 1) usually undergo further processing into raw materials or food sources, such as mango kernel flour (Figure 2). According to Shabeer et al. [10], mango kernels can be used to replace wheat flour in the composite flour technology for baked products. Nevertheless, the production processes of mango kernel flour, such as soaking, blanching, and drying are known to affect the quality of mango kernel flour. The presence of anti-nutrient components also restricted the application of mango seed kernels in the food industry. This review aims to provide an overview of their past and current perspectives. This review will cover the effect of processing parameters on the quality of mango kernel flour in terms of nutritional composition, functional properties, bioactive compounds, and their application in the food industry.

Figure 1. Mango kernel seed [11]

Figure 2. Processed mango kernel flour [11]

Overview of mango

Mangoes are grown in over 90 countries. According to the Food and Agriculture Organization (FAO), the harvested mangoes were over 28 million tonnes in 2014, accounting for 35% of global tropical fruit production. Asia accounts for around 77% of the worldwide mango supply, followed by the America and Africa, accounting for 13% and 9%, respectively. The Asian countries include India, China, Thailand, Indonesia, Pakistan, the Philippines, and Bangladesh. However, cultivation has extended to Mexico, Brazil, Madagascar, Tanzania, the Dominican Republic, Haiti, Brazil, and Australia [12]. Meanwhile, in Malaysia, mangoes are mostly found in northern regions such as Perlis, Kedah, and Northern Perak as they can thrive well under humid and dry conditions [13]. The most popular export mango cultivars are Kent, Tommy Atkins, Haden, and Keitt, which have a red blush and are fibreless, harder, and more suited for long-distance shipping compared to other cultivars [12]. Whereas in Malaysia, the famous mango clones planted are 'Harumanis', 'Maha 65', 'Masmuda', 'Sala', 'Chok Anan', and 'Siam Panjang' [13]. Generally, mango has an oval shape covered with leathery skin that changes colour from green to yellow when ripe [14] (Figure 3). The ripening stage of mango can be identified by its colour and texture, as it will turn from green to reddish orange [15] or yellow when ripe [16]. Unripened mangoes are extremely popular in Asia, but ripe mangoes are mostly consumed in the West [17].

The term "beak" is used to describe the shape of the mango as it has the characteristic of a conical projection. Large and fleshy mango fruits can vary depending on their shape, size, colour, fibre content, flavour, and aroma [18]. Depending on the cultivar, mango seeds appeared hairy or fibrous on the surface of the single flat oblong [19]. According to Beyene and Araya [15], the weight of mangoes can be up to one kilogramme depending on the cultivars, and it takes about three to six months to fully mature. The mango seed makes up roughly 10-25% of the overall weight of the fruit, while the kernel makes up about 45–85% of the seed's weight, which is about 20% of the total weight of the fruit [19]. In addition, the size of a mango and its kernel followed by their nutritional value can be determined by the mango's type, climate, ripening stage, cultivation, region, or harvesting time [20]. Moreover, Asia has the highest consumption levels, followed by Latin America, Africa, and Australia [17].

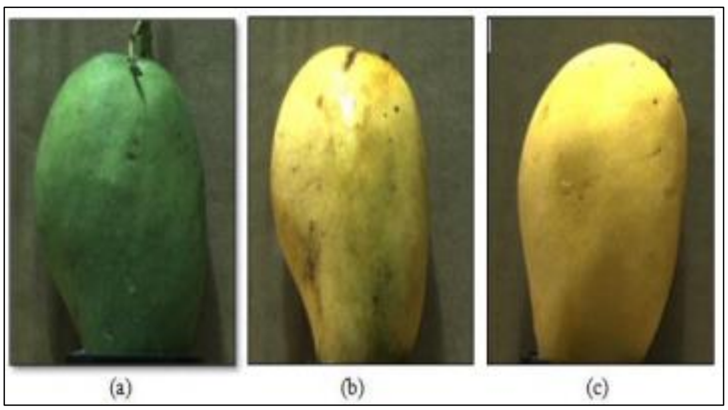

Figure 3. Different ripening stages of Chokanan mango: (a) Unripe fruit, (b) Yellowish-green peel, (c) Ripe fruit [14, 21]

Application of mango kernel flour in food industry

The demand for bakery products has increased the use of wheat flour [11, 22]. However, problems such as inadequate supply of wheat flour [23], higher cost, and geographical scarcity [11] have become the main factors in political and economic issues [23]. Therefore, a new alternative source of flour was introduced by converting mango kernels into mango kernel flour. Wheat flour can be substituted partially with mango kernel flour as composite flour due to its aesthetic chemical and functional properties. According to Das et al. [22], mango kernel flour can be a rich source of dietary minerals as the amount of ash in mango kernel flour (2.16%) is higher than in wheat flour (0.54%). Furthermore, the incorporation of mango kernel flour in the production of bakery products can lower the use of shortening agents as the fat content in mango kernel flour is 12 times higher than the fat content in wheat flour. Mango kernel flour has a lower swelling index compared to wheat flour, making the flour ideal and acceptable to be applied in extruded products such as noodles [22, 26]. Mango kernel flour and wheat flour had a crude fibre content of 1.16% and 0.42%, respectively. Because of its high fibre content, mango kernel flour can assist in improving digestion. On top of that, the amount of oil absorption capacity for mango kernel flour (0.94 grams) is lower than wheat flour (1.26 grams) [22]. The capability of medium oil absorption by flour implies that it may be used to make bread items [26]. This is because oil functions as a flavour keeper and enhances mouthfeel; thus, flour's capacity to absorb oil is critical as it is also related to the occurrence of rancidity and storage stability [29].

Several studies have described the application of mango kernel flour in cake production as it consists of many nutritional compositions such as fat, energy, protein, calcium, potassium, and magnesium [11]. Aside from cakes, the addition of up to 25% mango kernel flour to wheat flour produced cookies with satisfactory sensory properties and improved the quality of cookies in terms of physical properties and colour [1]. Gumte et al. [24] concluded that 30% mango kernel flour is the optimum amount to be added in the biscuits production because the proximate composition of the whole biscuit is 2.56% moisture, 5.21% protein, 14.06% fat, 1.92% ash, and 74.68% carbohydrate. This indicates that adding mango kernel flour to biscuits can produce a product with nutraceutical properties and good sensory evaluation results. Moreover, adding 20% of defatted mango kernel flour to bread also increases the nutritional properties [25]. According to Lakshmi et al. [26], mango kernel flour has a good foaming capacity and is suitable to be used in the preparation of whipped topping, ice cream, frozen desserts, breads, and cakes. Overall, mango kernel flour seems to potentially minimise the use of wheat flour, which can be incorporated into different baking products such as cakes, cookies, biscuits, and bread.

Effect of processing parameters

Research gaps on the mango kernel flour

The processing parameters involved in the production of mango kernel flour include soaking, blanching, and drying steps. Table 1 shows various ranges of processing parameters result in different properties of mango kernel flour. The purpose of soaking is to soften the kernels and remove anti-nutrients [11]. Mango kernels are recommended not to soak for more than 24 hours as it will reduce the protein content due to protein solubilisation. Moreover, the ash level at 72 hours is the lowest, which might be attributed to mineral leaching from the kernel, particularly the more soluble ones [8]. This can be supported by Mwaurah et al. [3] as the soaking process needs to be minimised in order to get a high amount of protein and fat content. Meanwhile, Gumte et al. [27] concluded that the soaking time used is best at 18 to 20 hours, but different results were obtained when the kernel was soaked for only 30 minutes in another study conducted by Das et al. [22]. Therefore, a maximum of 24 hours of soaking time is recommended for processing mango kernel flour in order to ensure excellent nutritional status since, at this level, the reduction of anti-nutrients to an acceptable level and an insignificant decrease of minerals is assured [8].

Blanching aims to inactivate the polyphenol oxidase (PPO) enzyme in order to preserve the quality and increase the shelf life of the food during storage. However, blanching also induces chemical changes in fruit by reducing the phytochemical compounds and organoleptic properties. Based on Ojha et al. [28], blanching the mango kernel flour at 45℃ for 2 minutes caused a reduction in water absorption capacity (131.67%) and oil absorption capacity (72.60%) as compared to untreated mango kernel flour, whereby the reported water absorption capacity and oil absorption capacity were 173.33% and 80.00%. In contrast to Florence et al. [29], blanched mango kernel flour has a higher water absorption capacity (230.75%) and oil absorption capacity (212.60%) as compared to unblanched mango kernel when the blanching parameter was set at 100℃ for 10 minutes. This indicates that the blanching process has improved the functional properties of the mango kernel flour. Nevertheless, further research should be conducted to investigate the optimum parameters of the blanching process in producing high quality mango kernel flour.

Drying is one of the popular technological methods used to inactivate the enzymatic degradation and extraction of functional components [30]. For example, Uzombah et al. [8] demonstrated the effect of different drying temperatures on the quality of mango kernel flour at 65℃, 75℃, and 85℃ for 24 hours. The results showed that the drying process affected the fat, protein, ash, and fibre content, in which the amount of nutrients decreased with increased temperature. Ekorong et al. [30] reported that the effects of drying time and temperature play a role in the moisture content and total polyphenol of mango seed kernels. Figure 4 illustrates that the increment of drying temperature from 40℃ to 80℃ resulted in a reduction of moisture content of 13.1%, which is caused by the increase in permeability to vapour. For drying time, the moisture content of the mango seed kernels initially dropped from 23.20% w/w at 6 hours to a minimum of 9.30% w/w at 56 hours and then rose up to 10.30% w/w at 69 hours. This can be explained by the fact that when air contained the maximum amount of vapour possible, the vapour exerted a saturation vapour pressure because the quantity of water vapour present was less than the maximum, thus the air took up more moisture. Meanwhile, the decrease in total polyphenol from 1.20 mg/g to 0.20 mg/g is due to the degradation of phenolic compounds at a higher temperature. Therefore, a drying step is needed to obtain the product in powder form and reduce the moisture content for better storage stability. Even though phenolic compounds are heat-sensitive, an increase in total polyphenols was detected as the drying duration increased. As shown in Figure 5, it began at 1.20 mg/g after 6 hours and increased to 1.38 mg/g after 69 hours. According to Ekorong et al. [30], this may be accounted for by the sum of the concentrations of the different phenolic acids in the free fraction, which increased significantly as the drying time increased. Subsequently, study on the optimum drying temperature and time is required to produce high-quality mango kernel flour.

Table 1. Different processing parameters of mango kernel flour

Author	**Soaking Time (h)**	**Blanching Temperature (℃)**	**Blanching Time (min)**	**Drying Temperature (℃)**	**Drying Time (H)**	**Properties of Mango Kernel Flour**
Florence et al. [29]	-	100	10	30	964	● Blanched mango kernel flour has higher water absorption capacity and oil absorption capacity as compared to unblanched mango kernel flour
Ojha et al. [28]	48	45	2	60	7	● Soaking and blanching reduced ash and fibre but increased protein, fat, and carbohydrate content ● Soaking and blanching caused a reduction in water absorption and oil absorption capacity ● Soaking and blanching reduced bioactive compounds (polyphenol, ascorbic acid, flavonoids, and tannin)
Das et al. [22]	0.5	-	-	65	16	● Functional properties: higher bulk density and water absorption capacity than wheat flour ● Nutritional value: higher ash, fibre, fat and energy content than wheat flour

Table 1 (cont'd). Different processing parameters of mango kernel flour

Author	Soaking Time (h)	Blanching Temperature (°C)	Blanching Time (min)	Drying Temperature (°C)	Drying Time (H)	Properties of Mango Kernel Flour
Uzombah et al. [8]	24, 48, 72	100	3	65,75, 85	24	• Soaking time affected the tannin, fibre, ash, and fat content • Dying temperature affect fat, protein, ash, and fibre • Drying and soaking increase the carbohydrate content
Gumte et al. [27]	18–20	-	1–2	60	5	• Reduced nutritional values: protein, ash, and fibre • Reduced tannin and flavonoids

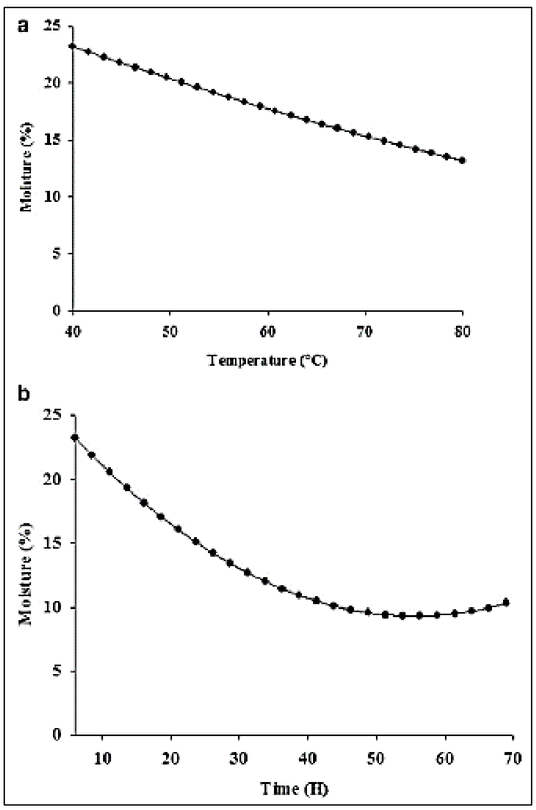

Figure 4. Effects of drying temperature and time on the moisture content of mango seed kernels [30]

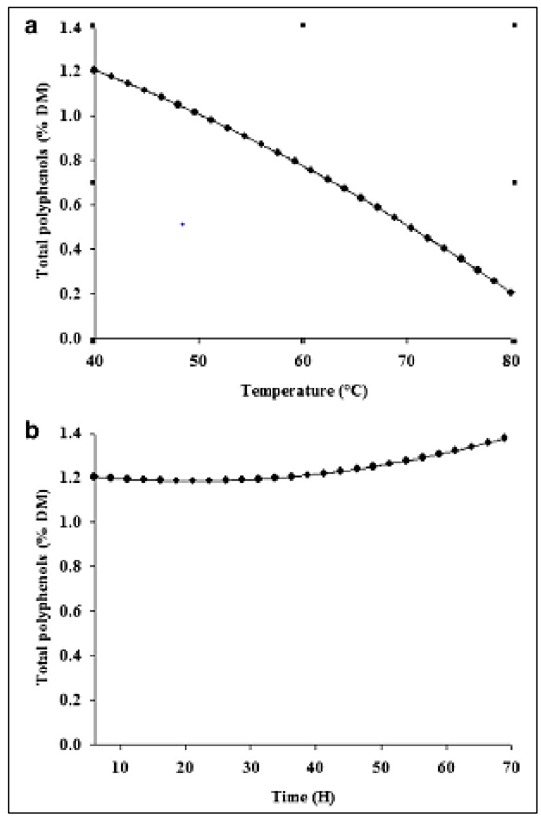

Figure 5. Effects of drying a) temperature and b) time on the total polyphenol content of mango seed kernels [30]

Nutritional composition

Mango kernel flour has shown that it is rich in carbohydrates, protein, and fat, which fit the nutrients that are needed in the human body. According to Mas'ud et al. [19], the nutritional compositions of mango kernel flour include moisture, carbohydrate, crude protein, total lipid, crude fibre, and ash content with their respective values of 9.20–9.60%, 36.20–39.30%, 5.20–6.60%, 6.00–7.20%, 2.20–2.50 %, and 2.90–5.50%, respectively. However, a few processing parameters have been identified to affect the quality of the produced mango kernel flour, including soaking, blanching, and drying time and temperature, as shown in Table 2. According to Uzombah et al. [8], soaking and drying parameters have affected the protein content. This is because of the protein denaturation and solubilisation at higher drying temperatures and longer soaking time. Besides that, Gumte et al. [27] also found the protein content of the raw mango kernel (10.02%) had slightly reduced after being processed into mango kernel flour (9.36%). Das et al. [22] deduced that an increase in drying temperature and time has prolonged the uptake of moisture, hence reducing the moisture content in mango kernel flour.

In addition to this, Sogi et al. [31] mentioned that drying temperature had affected the moisture content by increasing the vapour permeability, allowing the pore structure to remain open, hence decreasing the moisture content. Meanwhile, for fat content, Uzombah et al. [8] reported that an increase in drying temperature resulted in higher fat reduction, which is due to fat oxidation. In contrast to Ojha et al. [28], soaked mango kernel powder has higher fat content (10.17%) as compared to blanched (9.63%) and untreated mango kernel powder (9.53%). They proposed that the soaking process had resulted in the swelling of the kernel, thus increasing the fat content. Similarly, the ash and fibre content in mango kernel flour have also been reduced by the treatment of soaking and blanching due to the leaching loss of minerals [8], [28]. At the same time, soaking and drying have increased the carbohydrate content. This can be explained by the fact that soaking tends to reduce other components such as anti-nutrients that can form complexes with the nutrient. In contrast, increasing the drying temperature has accelerated the moisture removal process, increasing the carbohydrate content [8].

Table 2. Effects of processing parameters on the nutritional compositions of mango kernel flour

Nutritional Composition	Soaking	Blanching	Drying
Protein	• Longer soaking time solubilised the protein, hence reducing the protein content in mango kernel flour [8]	-	• Protein content in mango kernel flour is denatured at higher temperature [8]
Moisture	-	-	• The higher the drying temperature and time, the higher the uptake of moisture [22] • Drying temperature influenced the vapour permeability, thus affecting the moisture content [31]
Fat	• Soaking process caused the kernel to swell, thus increasing the fat content [28]	-	• Reduced the fat content in mango kernel flour through oxidation of fat at higher temperatures [8]

Table 2 (cont'd). Effects of processing parameters on the nutritional compositions of mango kernel flour

Nutritional Composition	Soaking	Blanching	Drying
Ash & Fibre	• Longer soaking time has reduced the amount of ash in mango kernel flour [8]	• Blanching process affected the ash and fibre content through leaching loss of minerals [28]	-
Carbohydrate	• Reduced other components that can form complexes with the nutrients, thus increasing the carbohydrate [8]	-	• Facilitated the concentration of carbohydrates by increasing the removal of moisture at higher temperatures [8]

Functional properties

Table 3 shows the effect of processing parameters on the functional properties of mango kernel flour, such as bulk density, oil absorption capacity, and swelling index. Das et al. [22] found that the bulk density in mango kernel flour is higher (0.63 g/mL) than wheat flour (0.58 g/mL). Based on Ojha et al. [28], the bulk density of mango kernel flour has increased after the treatment of soaking and blanching compared with untreated mango kernel flour. Sogi et al. [31] mentioned that higher amounts of bulk density might be due to excess tissue shrinkage during the drying process. This phenomenon indicates that processing parameters greatly influence the functional properties of mango kernel flour. The amount of oil absorption capacity is crucial in determining the product's sensory properties. This is because oil functions as a flavour keeper and enhances mouthfeel; thus, flour's capacity to absorb oil is critical [26]. Ojha et al. [28] showed that the oil absorption capacity of mango kernel flour has decreased after being soaked for 24 hours and blanched at 45℃ for 2 minutes, where the amount of oil absorption capacity for untreated mango kernel flour (80.00%) is higher than soaked mango kernel flour (60.00%) and blanched mango kernel flour (72.60%). The measurement of the swelling index is used to describe the gelatinisation of starches and flours [26].

Das et al. [22] demonstrated the soaking of mango kernels for 30 minutes and dried at 60–65℃ for 15–16 hours, and the obtained swelling index was 1.45 g/g. Surprisingly, the result is in contrast to Lakshmi et al. [26] as the swelling index for mango kernel flour obtained from three different types of mangoes (Neelam, Totapuri, and Alphonso) is 10.40 to 10.83 g/g in which the stone kernels were soaked for 48 hours and dried at 50℃ for 2 hours. In comparison with wheat flour, the swelling index is 3.54 g/g, while for durian seed flour, the swelling index is 8.03 g/g [32]. The lower amount of swelling index is due to the higher fat content in mango kernel flour, which resists starch gelatinisation [22]. Therefore, the processing parameters in mango kernel flour production should be optimised in order to enhance the functional properties of mango kernel flour and obtain high-quality mango kernel flour.

Table 3. Effects of processing parameters on the functional properties of mango kernel flour

Functional properties	Soaking	Blanching	Drying
Bulk density	• Increased the bulk density of soaked mango kernel flour compared to untreated mango kernel flour [28]	-	• Increased the amount of bulk density through the shrinkage of excess tissue [31]
Oil absorption capacity	• Decreased the amount of oil absorption capacity in soaked mango kernel flour (60.00%) compared to untreated mango kernel flour (80.00%) [28]	• Lowered the oil absorption capacity of blanched mango kernel flour (72.80%) compared to untreated mango kernel flour (80.00%) [28]	-
Swelling index	• The swelling index of mango kernel flour is 1.45 g/g when soaked for 30 minutes [22] • The swelling index of mango kernel flour is 10.40–10.83 g/g when soaked for 48 hours [26]	-	• The swelling index of mango kernel flour is 1.45 g/g when dried at 60–65°C for 15–16 hours [22] • The swelling index of mango kernel flour is 10.40–10.83 g/g when dried at 50°C for 2 hours [26]

Bioactive compounds

Generally, the processing parameters influence the amounts of bioactive compounds in mango kernel flour, such as ascorbic acid, tannin, polyphenol, and antioxidants (Table 4). According to Ojha et al. [28], the value of ascorbic acid present in blanched mango kernel powder is 112.00 mg/100 g, whereas in soaked mango kernel powder it is 119.33 mg/100 g. In contrast to Mas'ud et al. [19], the amount of ascorbic acid obtained in the mango kernel flour is 66.8 to 73.10 mg/100 g. The results are comparable with those of Sogi et al. [31] as the amount of ascorbic acid found in mango kernel powder is 61.22 to 74.48 mg/100 g. The researcher mentioned that the lower value of ascorbic acid is influenced by the thermal degradation and oxidation during the processing method. Tannin is one of the anti-nutritional substances found in raw mango kernel seed [33]. Besides reducing the availability of nutrients, tannin has astringent properties that contribute to the bitter principle and sour taste [27]. Thus, tannin needs to be removed before being applied in food or feed to reduce its toxic effect (about 75% of tannin in hydrolysable form). Soaking is an important step in this process because it promotes the leaching loss of anti-nutrients such as tannin from the mango seed kernel, but it should be done in less than 24 hours to avoid protein loss.

The total polyphenols found in mango seed kernel flour are 62.40 to 72.90 mg [19]. Nevertheless, Ojha et al. [28] stated that the polyphenols consisting of mango kernel flour had been significantly reduced through the process of soaking and blanching as the number of polyphenols recorded in untreated mango kernel powder (1630.00 mg/100 g) is higher than the soaked mango kernel powder (1573.33 mg/100 g) and blanched mango kernel powder (1553.33 mg/100 g). This reveals that the treatments of soaking for 24 hours and blanching at 45°C for 2 minutes have affected the amount of polyphenol. Besides that, drying time and temperature also influenced the polyphenol content since the degradation of phenolic compounds occurs at high temperatures [30]. The antioxidant present in mango seed kernels is the highest compared to other fruit seeds such as jackfruit, avocado, and logan [34]. Unfortunately, the level of antioxidants found by Ojha et al. [28] in untreated mango kernel flour is 84.33%, which is higher than blanched mango kernel powder (68.33%) and soaked mango kernel powder (79.00%). This showed that the processing parameters of soaking for 24 hours and blanching at 45°C for 2 minutes have negatively affected the concentration of antioxidants exhibited by the mango kernel flour.

Table 4. Effects of processing parameters on bioactive compounds in the mango kernel flour

Bioactive compounds	**Soaking**	**Blanching**	**Drying**
Ascorbic acid	• Soaking process increased the amount of ascorbic acid in mango kernel flour [28]	• Blanched mango kernel flour has a lower amount of ascorbic acid compared to soaked mango kernel flour [28]	• The lower amount of ascorbic acid is affected by the thermal degradation and oxidation [31]
Tannin	• Soaking for less than 24 hours helps in the removal of antinutrients such as tannin.	-	-
Polyphenol	• Soaking for 24 hours affected the amount of polyphenol in soaked mango kernel flour compared to untreated mango kernel flour [28]	• Blanching at 45°C for 2 hours lowered the amount of polyphenols in blanched mango kernel flour compared to untreated mango kernel flour [28]	• Drying at a high temperature contributed to the degradation of phenolic compounds
Antioxidants	• Soaking for 24 hours has lowered the antioxidants in the soaked mango kernel (79.00%) compared to untreated mango kernel flour (83.44%) [28]	• Blanching at 45°C for 2 hours has reduced the antioxidants in blanched mango kernel (68.33%) compared to untreated mango kernel flour (83.44%) [28]	-

Challenges

Removal of tannin from mango seed kernel remains a big challenge in the production of mango kernel flour as it can negatively impact human health and reduce the bioavailability of nutrients. According to Bala et al. [35], soaking the mango seed kernel at 70–80°C removes the tannin significantly and effectively, but this treatment affects the protein content of the mango seed kernel. Besides that, processing activities have a different impact on the nutritional composition of the finished mango kernel product [3]. Thus, an optimum processing parameter for the production of mango kernel flour should be further investigated. On top of that, the palatability of mango kernel flour may be affected by the high tannin content. This is because tannin can impart a bitter taste and reduce the flour quality by discolouration [8]. Incorporating mango kernel flour up to or more than 50% is also undesirable in the food product. It can impart a bitter taste and cause the product to be slightly darker due to the high amount of total phenolic content. The properties of mango kernel flour in terms of nutritional, functional, and bioactive compounds have made it such a great deal, especially in the food industry. Hence, it is recommended to conduct a study on the specifications for safeguarding mango kernel flour against adulteration being commercialised in the industry. Furthermore, it is suggested for the mango kernel flour to apply the mango kernel flour as a functional food ingredient [19]. In addition, turning mango kernels into a valuable product would also reduce the kernel waste and keep the environment clean.

Conclusion

In conclusion, the steps involved during the processing of mango kernel flour greatly influenced the quality of mango kernel flour in terms of its nutritional composition, functional properties, and bioactive compounds. This is because soaking and blanching lead to leaching loss of certain nutrients, bioactive compounds, and functional properties, but at the same time, they help reduce the anti-nutrients, which refer to tannin. Meanwhile, the drying process reduces the protein, fat, moisture, ash, and fibre but also helps to increase the carbohydrate content, resulting in a high energy value. The presence of bioactive compounds in mango kernel flour, such as polyphenol and ascorbic acid, exhibited therapeutic value, which is high in antioxidants and is beneficial to human health. The functional properties of mango kernel flour make it potentially useful as a functional ingredient in food products, especially in bakery products. Further research on the optimisation of each of the processing steps is required in order to obtain high-quality mango kernel flour.

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References

1. Awolu, O. O., Sudha, M. L. and Monohar, B. (2018). Influence of defatted mango kernel seed flour addition on the rheological characteristics and cookie making quality of wheat flour. *Food Science Nutrition,* 6(8): 2363-2373.
2. Ediriweera, M. K., Tennekoon, K. H. and Samarakoon, S. R. (2017). A review on ethnopharmacological applications, pharmacological activities, and bioactive compounds of *Mangifera indica* (mango). *Evidence-based Complementry Alternative Medicines,* 2017: 6949835.
3. Mwaurah, P. W., Kumar, S., Kumar, N., Panghal, A., Attkan, A. K., Singh, V. K. and Garg, M. K. (2020). Physicochemical characteristics, bioactive compounds and industrial applications of mango kernel and its products: A review. *Comprehensive Review Food Science Food Safety,* 19(5): 2421-2446.
4. Izli, N., İzli, G. and Taskin, O. (2017). Influence of different drying techniques on drying parameters of mango. *Food Science Technology,* 37(4): 604-612.
5. Masibo, M. and He, Q. (2009). Mango bioactive compounds and related nutraceutical properties-a review. *Food Review International,* 25(4): 346-370.
6. Torres-León, C., Rojas, R., Contreras-Esquivel, J. C., Serna-Cock, L., Belmares-Cerda, R. E. and Aguilar, C. N. (2016). Mango seed: functional and nutritional properties. *Trends Food Sci Technology*, 55(2016): 109-117.
7. Jahurul, M. H., Zaidul, I. S., Ghafoor, K., Al-Juhaimi, F. Y., Nyam, K. L., Norulaini, N. A. and Mohd Omar, A. K. (2015). Mango (*Mangifera indica l.*) by-products and their valuable components: a review. *Food Chemistry,* 183: 173-180.
8. Uzombah, T. A., Awonorin, S. O., Shittu, T. A. and Adewumi, B. A. (2019). Effect of processing parameters on the proximate and antinutritive properties of mango kernel flour processed for food applications. *Journal Food Processing Preservation,* 43(10): e14131.
9. Diarra, S. S. (2019). Potential of mango (*Mangifera indica L.*) seed kernel as a feed ingredient for poultry: a review. *Worlds Poultry Science Journal,* 70(2): 279-288.
10. Shabeer, M., Sultan, M. T., Abrar, M., Suffyan Saddique, M., Imran, M., Saad Hashmi, M. and Sibt-e-Abbas, M. (2016). Utilization of defatted mango kernel in wheat-based cereals products: Nutritional and functional properties. *International Journal Fruit Sciences,* 16(4): 444-460.
11. Yatnatti, S., Vijayalakshmi, D. and Chandru, R. (2014). Processing and nutritive value of mango seed kernel flour. *Current Research Nutrition Food Science Journal,* 2(3): 170-175.

12. Ram, R. A., Rahim, M. A. and Alam, M. S. (2020). Diagnosis and management of nutrient constraints in mango. *Fruit Crops*, 2020: 629-650.
13. Afiqah, A. N., Nulit, R., Hawa, Z. E. J. and Kusnan, M. (2014). Improving the yield of 'Chok Anan' (MA 224) mango with potassium nitrate foliar sprays. *International Journal Fruit Sciences,* 14(4): 416-423.
14. Okpala, L. C. and Gibson-Umeh, G. I. (2013). Physicochemical properties of mango seed flour. *Nigeria Food Journal,* 31(1): 23-27.
15. Beyene, G. and Araya, A. (2015). Review of mango (*Mangifera indica*) seed-kernel waste as a diet for poultry. *Journal Biology Agriculture Healthcare,* 5(11): 156-159.
16. Lauricella, M., Emanuele, S., Calvaruso, G., Giuliano, M. and D'Anneo, A. (2017). Multifaceted health benefits of *Mangifera indica l.*(mango): the inestimable value of orchards recently planted in Sicilian rural areas. *Nutrients,* 9(5): 525.
17. Matheyambath, A. C., Subramanian, J. and Paliyath, G. (2016). Mangoes. In *Encyclopedia of Food and Health*: pp. 641-645.
18. Elsheshetawy, H. E., Mossad, A., Elhelew, W. K. and Farina, V. (2016). Comparative study on the quality characteristics of some Egyptian mango cultivars used for food processing. *Annals Agriculture Sciences,* 61(1): 49-56.
19. Mas'ud, F., Rifai, A. and Sayuti, M. (2020). Mango seed kernel flour (*Mangifera indica*): nutrient composition and potential as food. *Malaysian Journal Nutrition,* 26(1): 101.
20. Patel, G. N. and Kheni, J. (2018). Mango seed kernel, a highly nutritious food, should we continue to trash or use? *Journal Pharmacognosy Phytochemistrt, 7*(4): 04-07.
21. Bejo, S. K. and Kamaruddin, S. (2014). Determination of Chokanan Mango sweetness ('*Mangifera indica*') using non-destructive image processing technique. *Australian Journal Crop Sciences, 8*(4): 475.
22. Das, P. C., Khan, M. J., Rahman, M. S., Majumder, S. and Islam, M. N. (2019). Comparison of the physico-chemical and functional properties of mango kernel flour with wheat flour and development of mango kernel flour based composite cakes. *NFS Journal,* 17: 1-7.
23. Perez, I. C., Mu, T. H., Zhang, M. and Ji, L. L. (2017). Effect of heat treatment to sweet potato flour on dough properties and characteristics of sweet potato-wheat bread. *Food Science Technology International, 23*(8): 708-715.
24. Gumte, S., Taur, A., Sawate, A. and Kshirsagar, R. (2018). Effect of fortification of mango (*Mangifera indica*) kernel flour on nutritional, phytochemical and textural properties of biscuits. *Journal Pharmacognosy Phytochemistry, 7*(3): 1630-1637.
25. Amin, K., Akhtar, S. and Ismail, T. (2018). Nutritional and organoleptic evaluation of functional bread prepared from raw and processed defatted mango kernel flour. *Journal Food Processing Preservation,* 42(4): e13570.
26. Lakshmi, M., Preetha, R. and Usha, R. (2016). Mango (*Mangifera indica*) stone kernel flour-a novel food ingredient. *Malaysian Journal Nutrition,* 22(3): 461-467.
27. Gumte, S., Taur, A., Sawate, A. and Thorat, P. (2018). Effect of processing on proximate and phytochemical content of mango (*Mangifera indica*) kernel. *International Journal Chemical Studies,* 6(2): 3728-3733.
28. Ojha, P., Raut, S., Subedi, U. and Upadhaya, N. (2019). Study of nutritional, phytochemicals and functional properties of mango kernel powder. *Journal Food Science Technology Nepal,* 11: 32-38.
29. Florence, O. S., Abdoulaye, T., Tidiane, K., Rodrigue, K. N., Monon, K. and Rene, S. Y. (2020). Chemical composition, functional and antioxidant properties of mango seed kernel (Kent variety) flour grown in Korhogo (Ivory Coast). *International Journal Science Engineering Research,* 11(11) : 357-369.
30. Ekorong, F. J. A. A., Zomegni, G., Desobgo, S. C. Z. and Ndjouenkeu, R. (2015). Optimization of drying parameters for mango seed kernels using central composite design. *Bioresource Bioprocessing, 2*(1): 1-9.
31. Sogi, D. S., Siddiq, M., Greiby, I. and Dolan, K. D. (2013). Total phenolics, antioxidant activity, and functional properties of '*Tommy Atkins*' mango peel

32. and kernel as affected by drying methods. *Food Chemistry,* 141(3): 2649-2655.
33. Kumoro, A. C. and Hidayat, J. P. (2018). Functional and thermal properties of flour obtained from submerged fermentation of durian (*Durio Zibethinus Murr*.) seed chips using *Lactobacillus Plantarum*. *Potravinarstvo,* 12(1): 965.
34. Dakare, M. A., Ameh, D. A., Agbaji, A. S. and Atawodi, S. E. (2014). Chemical composition and antinutrient contents of yellow maize, raw and processed composite mango (*Mangifera indica*) seed kernel from Zaria, Kaduna State Nigeria. *International Journal Advance Research,* 2(7): 90-97.
35. Lebaka, V. R., Wee, Y.-J., Ye, W. and Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. *International Journal Environmental Research Public Health,* 18(2): 741.
36. Bala, S., Ameh, D., Omage, J., Bugaje, S., Makeri, M., Dikko, H. and Usman, M. (2013). Influence of processing method on the nutrients and antinutrients content of kernels of three Nigerian local mango (*Mangifera indica L*.) varieties. *Journal Applied Agriculture Research, 5*(1): 203-213.