

Characterization and potential of Arumanis mango seed kernel flour as an alternative food source

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Abstract

Agricultural waste, particularly mango seed kernels, is frequently thrown away without being exploited despite its promise as an alternative food source. This study investigates the properties and possibilities of Arumanis mango seed kernel flour as an alternative food product ingredient. The methods included collecting Arumanis mango seed samples, drying, milling into flour, and analyzing its physicochemical characteristics and functional properties. The results showed that Arumanis mango seed kernel flour has a moisture content of 7.45%, ash content of 1.40%, protein content of 7.38%, fat content 9.67%, carbohydrate content of 74.15%, starch content of 52.15%, amylose content of 22.44%, phenols 36.76 mg GAE/g, antioxidant activity 58.11%, resistant starch 22.54%, dietary fibre 12.15%. The crystallinity of Arumanis mango seed kernel flour was 27.10%, which showed a Type A pattern under X-ray diffraction. The functional group profile detected C=C aliphatic-aromatic at wave number 1608 cm⁻¹ and C=O aldehyde, ketone and ester at wave number 1714 cm⁻¹. Based on the above characteristics, Arumanis mango seed kernel flour can be used as a substitute for food products or an alternative raw material.

Key words: Mango seed kernel flour, Arumanis, food waste, alternative food source, nutritional characterization

Introduction

The food industry sometimes produces waste or by-products that are often ignored or not optimally utilized, especially in countries with high agricultural production. One of the most common horticultural wastes is mango seeds. Mango (*Mangifera indica* L.) is a renowned tropical fruit marketed in over 100 countries (Mwaurah *et al.*, 2020). Indonesia ranks among the foremost mango-producing nations globally. According to the Central Statistics Institute, in 2024, mango production in Indonesia in 2023 reached 3.3 million tonnes.

Meanwhile, Bali is among the top 10 provinces that produce mangoes. With the high production of mangoes, the amount of waste generated is also substantial. Mas'ud *et al.* (2020) noted that mango pulp contributes to carbohydrates, vitamins, and minerals. On the other hand, mango seeds are not commercially utilised and are viewed as waste. Moreover, Das *et al.* (2022) claim that mango seeds account for waste material between 17 to 25 % of the total fruit, and the seed kernel ranges from 45-75% of the total seed contingent upon the mango type. The mango seed kernel is the part of the mango fruit called the endocarp, and inside the endocarp, there is a mango seed kernel that is usually utilized. Thus, the untapped potential of mango seeds is enormous, especially in developing alternative food ingredients.

Nutrient composition substantially influences the quality of alternative food components (Uzombah *et al.*, 2019). Comprising 58-80% starch, the high carbohydrate content makes mango seed kernels suitable for flour manufacture (Bangar *et al.*, 2021). Mwaurah *et al.* (2020) revealed that mango seed kernel flour (MSKF) has a high nutritional value, with protein content ranging

from 6.36% to 10.02%, carbohydrates of 32.34% to 76.81%, and fat content of 6% to 15.2% on a dry weight basis. Other studies claim that MSKF has a favourable nutritional profile, with high protein and fibre content, which promotes health (Mandha *et al.*, 2021). Thus, MSKF could be employed as a raw material in food items, both as a replacement and as an additional component, which should enhance the nutritional value of the end product.

Mango kernel fat (MKF) is a promising by-product of mango processing, offering a range of beneficial qualities that make it suitable for various applications. The fat content in mango kernels varies significantly across different varieties, with values ranging from approximately 3% to 12% on a dry basis (Dabiré *et al.*, 2024; Das *et al.*, 2022). MKF is characterized by a high content of saturated fatty acids, particularly stearic and palmitic acids, and a significant proportion of oleic acid, an unsaturated fatty acid (Oladapo *et al.*, 2021) (Kouassi *et al.*, 2024). These characteristics contribute to its potential as a cocoa butter alternative, especially in confectionery products (Nadeem *et al.*, 2016).

Studies prior to this one have revealed that mango seeds possess bioactive substances that promote health. Multiple investigations have found that MSKF is rich in certain phenolic compounds that exhibit antioxidant activity (Bordia *et al.*, 2023; Martínez-Olivo *et al.*, 2023). Castro-Vargas *et al.* (2019) and Nguyen *et al.* (2019) support this by showing that mango seeds are a significant source of polyphenols since the number of phenolic compounds detected in mango seed extract is 280.3 mg/g GAE. Consequently, including MSKF into diverse processed food products aids in minimizing waste, providing greater value, augmenting nutritional content, and improving the likelihood of ingesting healthful foods.

Arumanis mangoes are widely planted and a popular fruit in Indonesia and mostly in Bali which has led to a large harvest of seed kernels. These seed kernels are untapped with potential especially in the production of alternative food ingredients. The nutritional composition largely depends on the site of growth, climate, and production plans (Bangar *et al.*, 2021). It is therefore urgent that before they are used, they must determine and define the Arumanis mango seed kernels grown in Bali since this baseline information is currently not available. This paper explores the properties and potentials of Arumanis mango seed kernel flour (MSKF) as a viable alternative food source. This study aims to ensure that agricultural by-products are utilized maximally and that the trash is kept to a minimum and thus it is unlikely to contaminate the environment.

Materials and method

Materials: The study utilized Arumanis mango seeds collected from fruit juice vendors in Denpasar City, Bali. The original fruits were of uniform maturity and had been harvested 100-120 days after flowering from plantations in Buleleng, Bali. Chemicals for analysis include hexane solvent (Merck), Kjeldahl tablets (Merck), HCl (Merck, Germany), standard glucose (Merck), standard amylose (Merck), arsenomolybdat, ethanol PA (Merck), K₂SO₄ (Merck), and 95% alcohol (Onemed), DPPH pro analysis (Sigma-Aldrich, USA), gallic acid (Sigma-Aldrich), pepsin enzyme, amylase enzyme, pancreatin, folin-ciocalteu reagent (Merck, Germany). The leading equipment for analysis includes a spectrophotometer (Genesys 10S UV-VIS), an FTIR spectrometer (IR Prestige-21 Shimadzu), and an XRD spectrometer (PANalytical X'Pert PRO).

Sample preparation: This study used an exploratory method with the following preparation: Arumanis mango seeds were washed and cleaned from dirt. The mango seeds were split using a special knife, and then the kernels were taken and thinly sliced into *chips* with a thickness of ± 3 mm. The sliced mango seed kernels were soaked in water at the ratio of soaking water (1:5) for 15 minutes and then rinsed thoroughly under running water and drained. The mango seed kernels were dried using a dehydrator at 60°C for 9 hours. After drying, the material was mashed using a grinding machine and then sieved through an 80-mesh sieve. The resulting flour was preserved in an airtight jar at 4°C to maintain quality.

Chemical properties and analytical methods: The analysis of proximate composition included the determination of moisture, ash, protein, and crude fat according to the AOAC (2010) method, while carbohydrates were calculated by difference. Starch content was determined by Somogy's reducing sugar-Nelson method (Awodi *et al.*, 2022) and amylose content (Akhter *et al.*, 2024). Total phenolics were determined by the Folin-Ciocalteu method (Castro-Vargas *et al.*, 2019), and antioxidant activity was assessed using the DPPH method, as described by Das *et al.* (2022). Resistant starch testing was done using the multienzyme method (Wang *et al.*, 2022) with modifications. Dietary fibre content was determined using the multienzyme method (Rivera-González *et al.*, 2019).

Profile of flour: The crystallinity profile was quantitatively assessed using the modified approach outlined in the literature (Choudhary *et al.*, 2023). Functional group profiling was performed using Fourier Transform Infrared (FTIR) Spectrometry (Wang *et al.*, 2022).

Data analysis: The data obtained were analyzed descriptively, qualitatively and quantitatively.

Results and discussion

Chemical properties: The chemical characteristics of Arumanis MSKF have great potential as an alternative food source, as shown in Table 1. The moisture content of Arumanis MSKF in this study was relatively low at 7.45%. A low moisture content is essential for maintaining flour storage stability, reducing microbial activity, and overall food product quality. Similarly, research by Das *et al.* (2022) on ten mango varieties revealed that the moisture content in the flour ranged from 4.57% to 7.59% with an average of 6.03%. The National Standardisation Institute of Indonesia states that for flour used as food raw materials, such as flour, the moisture content must remain below 14% to maintain product quality and freshness. Other studies have shown that decreasing the moisture content of flour during the drying process can increase its shelf life.

The protein value of 7.38% indicates that Arumanis MSKF can be a potential source of protein for developing food products. Several studies by Das *et al.* (2022) showed that the protein content of several mango varieties ranged from 6.52 - 7.89%. Patiño-Rodríguez *et al.* (2020) mentioned that MSKF contains 5.29% protein. Mas'ud *et al.* (2020) also conducted similar studies, where the protein content of MSKF was 5.2-6.6%, respectively, lower than that of this study. The protein content of Ogbo and Saigo MSKF was 6.30 - 7% (Uzombah *et al.*, 2019). A balanced diet requires protein, and since mango seed meals contain sufficient protein, they will undoubtedly improve the nutritional quality of the product.

Table 1. Chemical properties of Arumanis MSKF

| Variables | Content (%) |
|---------------|-------------|
| Moisture | 7.45± 0.50 |
| Ash | 1.40± 0.07 |
| Protein | 7.38± 0.24 |
| Fat | 9.67± 0.32 |
| Carbohydrates | 74.15± 0.79 |
| Starch | 52.15± 1.70 |
| Amylose | 22.44± 1.77 |

The data were presented as mean \pm S.D (n=3)

Results showed that Arumanis MSKF's fat content was 9.67% (Table 1). According to Guehi *et al.* (2023), the fat content of MSKF in almond varieties was 19.46%. In contrast, Das *et al.* (2022) reported a more diverse range of 7.44-12.82% in 10 mango varieties, with an average of 9.35%, similar to the findings of this study. Likewise, Patiño-Rodríguez *et al.* (2020) found that the fat content of MSKF was 11.33%. Fat contributes flavour, texture, and stability to food products. Thus, this flour's fat can enhance the final product's organoleptic quality. This comparatively high-fat content can provide health benefits, depending on the type of fatty acids present. This flour's 9.67% fat content indicates its potential as a fat substitute in food products. In developing healthier products, using MSKF as a fat substitute can help reduce the amount of saturated fat in the diet without sacrificing flavour and texture. MKF is rich in stearic acid (30.3%-48.3%) and oleic acid (35.9%-47%) (Kouassi *et al.*, 2024). The presence of palmitic acid ranges from 8.84% to 10.66% (Oladapo *et al.*, 2021). The fatty acid profile suggests MKF can be used in trans-

fat-free formulations (Nadeem *et al.*, 2016). MKF has a melting point similar to cocoa butter, ranging from 24°C to 36°C, making it solid at room temperature (Nadeem *et al.*, 2016). The peroxide and acid values of MKF are within acceptable limits, indicating good oxidative stability (Dabiré *et al.*, 2024). The solid fat content (SFC) and crystallization behaviour of MKF are comparable to cocoa butter, with a predominant β' polymorph, which is desirable for confectionery applications (Mokbul *et al.*, 2022).

The ash content of Arumanis MSKF, at 1.40%, indicates that this flour has relatively little mineral content but can still contribute to dietary mineral requirements. Research by Das *et al.* (2022) and Guehi *et al.* (2023) showed that the ash content of MSKF almonds varied from 2.18 to 3.63%. In the MSKF Ogbo and Saigo varieties, the ash content ranged from 3.38% to 3.40% (Uzombah *et al.*, 2019). The MSKF Kagoogwa variety contains minerals, including Ca, K, Na, and Mg, at levels of 395, 163, 103, and 76.5 mg/100 g (Mandha *et al.*, 2021). The findings show that Arumanis MSKF can serve as a good energy source due to its high carbohydrate content of 74.15%. High-carbohydrate foods are staples in the human diet and are the primary energy source. Other studies found that MSK of different varieties has a carbohydrate percentage of roughly 70% (Bordia *et al.*, 2023; Guehi *et al.*, 2023; Uzombah *et al.*, 2019).

Starch is typically extracted from carbohydrate-rich food sources, including tubers, nuts, and grains. On the other hand, starch is essential in the food industry as a thickener, filler, binder and raw material or substitute for processed foods. Interestingly, starch is also used in various industries, including paper, textiles, and cosmetics, beyond its primary application in food. Familiar starch sources used as staple foods are corn, potatoes, rice, and wheat. The starch content found in Arumanis MSKF is relatively high at 52.15%. The high level of starch in the form of flour in Arumanis MSKF makes it potentially suitable for broader application in food products. Awodi *et al.* (2022) and Patiño-Rodríguez *et al.* (2020) reported that the starch content in MSKF can vary between 34, 6% to 58.6%. However, Bangar *et al.* (2021) found a higher range, from 58% to 80%, depending on the specific mango variety. With increasing interest in alternative ingredients, researchers are exploring potential starch sources, such as seeds. This can open up exciting opportunities to create a variety of food products, such as biscuits and bread, that not only increase nutritional value but also retain their delicious taste and texture (Saxena and Aman, 2021).

The amylose content of Arumanis MSKF is relatively high at 22.44%. Studies reported by several researchers indicate that the amylose content of MSKF varies. Bangar *et al.* (2021) reported that the amylose content of MSKF in several varieties ranges from 21% to 33%. Akhter *et al.* (2024) reported a similar finding: the amylose content of mango kernel starch ranges from 18.35% to 23.5%, depending on the extraction method used. The amylose content of MSKF Arumanis is higher when compared to avocado flour cultivar Landrace (17.46%) and Hass (19.73%) (De Dios-Avila *et al.*, 2022).

Functional food potential: Arumanis MSKF shows considerable potential as a functional food source due to its nutrient composition and bioactive components, as shown in Table 2. Research shows that the phenol content of Arumanis MSKF is 36.76 mg GAE/g. Das *et al.* (2022) report a different finding that the phenol content of MSKF is in the range of 23-28 mg GAE/g. Meanwhile, Nguyen

et al. (2019) report that MKO contains bioactive compounds, including mangiferin, kaempferol, catechin, quercetin, gallic acid, tannin, ellagic acid, alkylresorcinol, gallotannin, and benzophenone derivatives, which possess antioxidant abilities. As for mango seed kernel extract, the total phenolic compound content ranges from 18.19 to 200.35 mg GAE/g dry basis (db), depending on the type of solvent and extraction method used (Mwaurah *et al.*, 2020). In comparison, avocado seed flour extract has a lower phenol content, ranging from 80 to 135 μ g GAE/mL, indicating that avocado seeds are also a good source of phenols (Parinding *et al.*, 2021).

Table 2. Bioactive compounds and functional properties of Arumanis MSKF

| Variables | Content |
|-----------------------------|------------|
| Total phenol (mg GAE/g) | 36.76±1.17 |
| Tannin (mg TAE/g) | 19.74±2.53 |
| Antioxidant activity (%) | 58.11±1.35 |
| Resistant starch (%) | 22.54±0.39 |
| Total dietary fibre (%) | 12.15±0.81 |
| Soluble dietary fibre (%) | 0.86±0.11 |
| Insoluble dietary fibre (%) | 11.43±0.41 |

The data were presented as mean \pm S.D (n=3)

The measured tannin level in MSKF Arumanis was 19.74 mg TAE/g. Das *et al.* (2022) reported a higher average tannin level in some MSKs of 22.77 mg TAE/g. Tannins are bioactive compounds of the polyphenol class that can contribute to human health because they have antioxidant properties. Tannins are known to possess strong antioxidant properties, which can help protect body cells from free radical damage (Choudhary *et al.*, 2023; Nguyen *et al.*, 2019). However, although polyphenols in tannins function as antioxidants, high amounts will cause a bitter and astringent taste (Mwaurah *et al.*, 2020).

Castro-Vargas *et al.* (2019) explain that mango seed extract has high antioxidant activity due to its high phenol content. This is supported by this study, where the antioxidant activity of Arumanis MSKF reached 58.11%. Compared to avocado seed flour, which has 47% antioxidant activity, Arumanis MSKF exhibits higher antioxidant activity (Kumari *et al.*, 2024). The relationship between phenol levels and antioxidant activity is also evident, where this compound contributes to the ability of Arumanis MSKF to ward off free radicals, protecting the body from oxidative stress, *i.e.*, reducing cell damage, reducing the risk of degenerative diseases such as heart disease and cancer with antioxidant activity (Nguyen *et al.*, 2019). Therefore, this antioxidant activity is crucial for human health and can also increase the shelf life of food products containing MSKF. Mandha *et al.* (2021) reported that processing mango seeds can increase antioxidant potential, which supports their use in food products.

The resistant starch content in MSKF Arumanis is 22.54%, indicating that this flour can serve as a good source of fibre, surpassing avocado seed flour at 10.34% (Rivera-González *et al.*, 2019). Resistant starch is not digested in the small intestine, functioning as a prebiotic because it supports the growth of beneficial bacteria in the large intestine. In addition, resistant starch is a source of insoluble fibre that contributes to digestive health (Wang *et al.*, 2022). The link between resistant starch and dietary fibre suggests that MSKF can offer broader nutritional benefits, particularly in a healthy diet. A different finding was

reported in mango seed kernel starch, which contains more resistant starch than easily digestible and slowly digestible starch. The resistant starch content of mango seed kernel starch was 28.75% higher than that of Arumanis MSKF in this study (Patiño-Rodríguez *et al.*, 2020). Therefore, resistant starch from mango seeds can contribute to weight control and intestinal health.

The total dietary fibre content in MSKF Arumanis is 12.5%, with 0.86% soluble fibre and 11.43% insoluble fibre. Similarly, it was reported (Patiño-Rodríguez *et al.*, 2020) that mango seed kernel starch has a total dietary fibre content of 12.03%. Mandha *et al.* (2021) reported differently on the MSKF of the Kogoogwa variety, where the total dietary fibre was 23.4% higher than corn flour. Dietary fibre is essential to digestive health, helps prevent constipation, and can contribute to weight control. Insoluble fibre functions to increase stool mass and accelerate intestinal transit, while soluble fibre can help lower cholesterol and blood glucose levels (Shehabeldin *et al.*, 2021). The combination of soluble and insoluble fibre in Arumanis MSKF demonstrates its potential for use in food product formulation to support digestive health. The relationship between resistant starch and dietary fibre suggests that MSKF can offer broader nutritional benefits, particularly in a healthy diet. This is supported by Saxena and Aman (2021), who reported that fibre from mango seeds can improve the quality of food products such as biscuits and bread.

MKF can be used in the production of margarine and other bakery products, offering a healthier fatty acid profile by reducing trans fats. Its high phenolic content provides antioxidant properties, making it a potential natural preservative in food products (Nadeem *et al.*, 2016). While MKF shows great potential, its quality can be influenced by factors such as the mango's ripening stage and the extraction method used. For instance, the fatty acid profile and oxidative stability can vary with different drying and extraction techniques (Oladapo *et al.*, 2021). Additionally, the environmental impact of utilizing mango kernels, which are often considered waste, highlights the sustainability aspect of MKF production (Dabiré *et al.*, 2024).

The crystallinity of flour: The crystallinity of starch is a crucial variable that influences the functional properties of starch, including viscosity and gelatinisation. Figure 1 shows the XRD pattern of Arumanis MSKF. X-ray diffraction analysis revealed diffraction peaks at angles of 15.11°, along

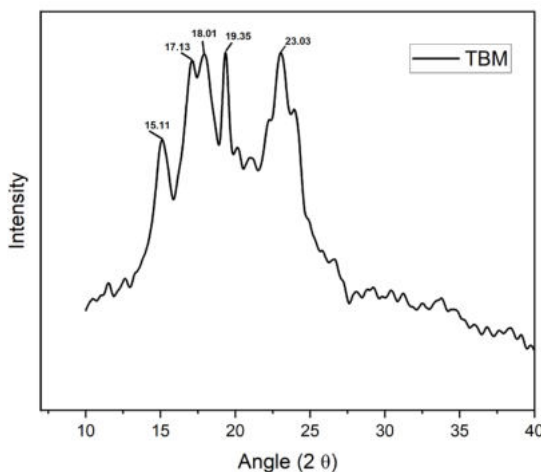


Fig 1. X-ray diffraction of Arumanis MSKF

with a sharp, small peak at 19.35° and unresolved double peaks at angles of 17.13° and 18.01°. These results indicate that Arumanis MSKF has an A-type crystal with a crystallinity level of 27.10%. Ferraz *et al.* (2019) reported that mango seed starch also exhibits similar diffraction peaks, which are well-detected and describe crystallinity at angles of 15°, 19.3°, and 23°, as well as a doublet at an angle of 17°. The flour and the mango seed kernel show a semi-crystalline structure with a type A crystal pattern (Patiño-Rodríguez *et al.*, 2020).

The diffraction peaks at around 15° and 23° indicate a typical A-type crystal structure. They are commonly found in the starch and flour of grains and cereals, indicating an ordered crystal arrangement that influences the functional characteristics of the starch. Bangar *et al.* (2021) and Choudhary *et al.* (2023) reported similar diffraction peaks in mango seed starch, with crystallinity values of 29.23% and 40.08%, respectively. This proves that the A-type crystal structure is a characteristic of Arumanis mango seed flour (MSKF). Small, sharp, pointed peaks at 19° are generally not found in mango seed starch compared to flour. This may indicate the possibility of interactions between the fairly complex components of flour, such as proteins and fibres, which have implications for its functional properties (Tian *et al.*, 2023). In addition, variations in diffraction peaks can arise from differences in the chemical composition and morphology of starch between sources. Unresolved double peaks at angles (17° and 18°) indicate a more complex crystal structure in MSKF and may affect the gelatinisation profile and digestibility. Ferraz *et al.* (2019) reported that variations in crystal peaks can be caused by chemical modification or changes in processing.

Wang *et al.* (2022) reported that the starch from avocado seeds has a crystallinity level of 10.5% to 12.8%. Tian *et al.* (2023) reported that rice starch has a crystallinity level of 21%. Although this is lower than Arumanis mango seed kernel flour (MSKF), the crystal structure of avocado seeds and rice flour also shows type A characteristics. Higher crystalline starches resist heat changes more effectively, impede water access, and elevate viscosity. Similar studies revealed that the degree of crystallinity also affects the gelatinisation temperature; more crystalline starches usually have a higher gelatinisation temperature, as they require more energy to break the connections between starch molecules (DU *et al.*, 2023). So, the higher crystallinity in Arumanis mango seed flour can be expected to produce improved rheological characteristics.

Functional group profile: Wavenumbers from the FTIR spectrometer examination reveal the functional group profile of MSKF Arumanis, as displayed in Fig. 2 and Table 3 (Anonymous, 2025). The wavenumber spectrum at 3541 cm⁻¹ reveals the presence of the alcohol (O-H) functional group; at 2930 cm⁻¹, the alkane (CH₃-CH₂-CH) functional group; and at 1714 cm⁻¹, the ester, ketone, and aldehyde (C=O) functional groups. Moreover, wave number 1608 cm⁻¹ points to the functional group of aromatic alkenes (C=C), wave number 1448 cm⁻¹ points to the functional group of alkanes (C-H), wave number 1337 cm⁻¹ points to the C-N and O-H stretching functional groups, and wave number 1209 cm⁻¹ points to the C-O functional group. These functional groups mirror the molecular structure, supporting the richness of the nutritional profile and bioactive components of Arumanis MSKF, making it relevant as an alternative food source with possible functional food qualities.

Table 3. Wave numbers and functional groups of Arumanis MSKF

| Standard wave region (cm ⁻¹) | Standard functional groups | Wave number MSKF (cm ⁻¹) | Functional groups MSKF |
|------------------------------------------|----------------------------|--------------------------------------|------------------------------------------------|
| 3200 - 3650 | alcohols, phenols | 3541 | O-H |
| 2850 - 3000 | alkane | 2930 | C-H (CH ₃ , CH ₂ dan CH) |
| 1710 - 1740 | esters, ketones, aldehydes | 1714 | C=O |
| 1600 - 1680 | alkenes | 1608 | C=C |
| 1400 - 1465 | alkanes | 1448 | C-H |
| 1310 - 1390 | aromatic amine and phenol | 1337 | C-N and O-H |
| 1200 - 1225 | ester | 1209 | C-O |

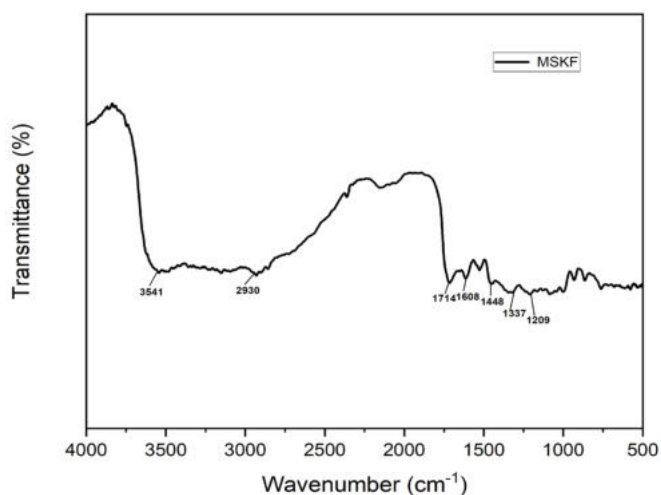


Fig 2. Wave number spectrum of Arumanis MSKF

The broadband and strong peak at a wave number of 3541 cm⁻¹ indicate the presence of a hydroxyl group (O-H). The detected peak is thought to originate from starch, protein, or phenolic compounds, indicating the presence of bioactive components in MSKF Arumanis. These compounds generally contribute to the gel-forming ability, water-binding properties, and ease of dissolution, making them highly sought after in food product applications. This finding is similar to similar peaks identified in avocado seed starch research, linking these structures to their potential functionality (Wang *et al.*, 2022).

The medium band in the 2930 cm⁻¹ spectrum is usually associated with C-H vibrations of aliphatic alkanes (R-CH₂-CH₃). It indicates the presence of glucose, lipids or fatty acids in the structure (Ferraz *et al.*, 2019). In MSKF, this peak indicates that the material has a significant lipid content, which can provide emulsifying and stabilising properties in food applications. Research by Wang *et al.* (2022) on avocado seeds also found similar peaks, indicating that avocado seeds have a high lipid content. This suggests that mango and avocado seeds have identical potential in developing food products that require emulsifying properties.

A peak at 1714 cm⁻¹ indicating C=O vibrations of esters or carboxylic groups, ketones or aldehydes associated with lipid compounds and antioxidants indicates added value in food products. Similar results were found in esterified modified mango seed starch (Ferraz *et al.*, 2019). The presence of active compounds, such as phenolics, indicated by a peak at 1738 cm⁻¹ in baraka fruit and avocado seed flour, contributing to antioxidant activity, as evidenced by the same peak in FTIR (De Dios-Avila *et al.*, 2022; Iriany and Angkasa, 2021). The peak at 1608 cm⁻¹ corresponds to aliphatic (alkene) C=C bonds, reflecting aromatic compounds and indicating the presence of bioactive compounds. This peak enhances the availability of bioactive compounds that have been shown to possess antioxidant properties and advantageous functional attributes in food matrices. Previous studies on avocado seed flour and banana flour highlighted similar structures, indicating the potential

of these compounds to add nutritional and health value to foodstuffs (Rivera-González *et al.*, 2019)

The wavenumber of 1448 cm⁻¹ indicates the presence of a powerfully intense C-H alkane functional group. Alkanes are aliphatic hydrocarbon compounds without saturated and unsaturated benzene rings. The wave number of 1337 cm⁻¹ indicates the presence of a C-N group, suggesting that the flour still contains amine compounds and O-H as low-intensity phenol compounds. The wave number of 1209 cm⁻¹ indicates the presence of a C-O ester group, suggesting that the flour contains lipid compounds with high intensity. According to Musa and Sagagi (2023), another peak in the range of 1000-1260 cm⁻¹ in this spectrum is caused by the C-O (alkoxy) band in the mango seed starch component.

FTIR MSKF Arumanis analysis showed that MSKF Arumanis has rich and varied chemical characteristics, which include starch, protein, lipids, and phenol. Or bioactive components compared to pure starch. This can be supported by the fact that the entire MSKF spectrum has higher peaks. The peaks observed in the FTIR spectrum indicate that this material is suitable for application in the development of food products, particularly those with enhanced properties such as water absorption capacity, viscosity, and thermal stability, as well as its potential as a functional ingredient.

MSKF Arumanis, with high carbohydrate, starch, dietary fiber, phenol content, and antioxidant activity, demonstrates excellent potential as an alternative food ingredient due to its favorable nutritional and functional properties, including 27.10% starch crystallinity. The presence of functional groups such as aliphatic aromatics (C=C at 1608 cm⁻¹) and carbonyls (C=O at 1714 cm⁻¹) in MSKF supports its use in developing healthier, sustainable food products like bread, biscuits, and flakes, warranting further research into its effects on product quality, nutrition, and consumer acceptance.

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