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MINI REVIEW

Factors affecting the properties of rice flour: a review

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Abstract

Rice (*Oryza sativa* L.) is a global essential food. Rice flour production had a significant upsurge, leading to various development in rice-based food products. The properties of starch within rice flour are generally affected by different factors, resulting in rice flour with various physicochemical and functional properties. This article summarized the several factors that affect rice flour properties, including environmental conditions in terms of temperature extreme and soil conditions, milling methods, amylose and amylopectin composition, and endogenous protein and lipid. Overall, environmental conditions in extreme temperatures can influence the amylose content, altering the amylopectin chain length and functional and thermal properties, to be specific gelatinization temperature and pasting properties. As for soil conditions like water deficiency and salinity stress could affect the pasting properties, reduce amylose content, increase the swelling rate, and pasting properties due to the alteration of protein endosperm level in rice flour, respectively. Factors such as the milling method are capable of influencing the starch characteristics within rice flour, and wet-milled rice flour is more applicable in the development of gluten-free rice bread than dry-milled rice flour. Amylose and amylopectin composition were found to affect the texture of final products and the physicochemical properties of rice flour, such as swelling capacity, gelatinization temperature and pasting properties. Whereas endogenous protein and lipid can influence the swelling properties, water solubility index, gelatinization temperature and retrogradation rate by the formation of complexes with amylose, called amylose-protein and amylose-lipid. In general, different factors could lead to vast properties of rice flour that can affect its performance of flour.

1. Introduction

Rice (*Oryza sativa* L.) is an essential global food. As a staple food for more than half of the world's population, rice has been relied on as a caloric source (Asmeda *et al.,* 2016). Globally, over 3.5 billion people consume rice (Fiamohe *et al.,* 2018). It is grown initially to be consumed as a boiled rice grain, and the utilisation of rice flour as an ingredient is common (Chusak and Adisakwattana, 2020). Nonetheless, rice has various types with diverse qualities. According to Custodio *et al.* (2019), the perception of rice quality varies among regions, countries, and urbanization levels. Essentially, the quality of rice not only covers pre-harvest and post-harvest factors, such as the cultivation area of paddy, harvesting, and processing but encompasses the physical and chemical properties of rice (Lum, 2017). According to Henrita *et al.* (2015), physicochemical characteristics can be used as a medium for marketing purposes by providing information correspondingly to consumers that prioritize a healthy lifestyle.

Rice flour production had a significant upsurge, thus increasing various development in rice-based food products, such as gluten-free bread, rice cakes, rice noodles, and infant food (Zhu *et al.,* 2010; Kim, 2013; Araki *et al.,* 2016). This phenomenon occurred because rice flour possesses a neutral flavour and low sodium content, and it is hypoallergenic, easily digested, and easily absorbed by the human body (Masure *et al.,* 2016; Roman *et al.,* 2019; Ren *et al.,* 2020). Rice flour is known as a good ingredient in gluten-free products because of its low level of prolamins compared with wheat flour (Kim, 2013). In this case, prolamins in wheat or any related grains can trigger celiac disease symptoms (Balakireva and Zamyatnin, 2016). Hence, rice flour is

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suitable for the development of gluten-free food, especially for gluten-related disorders patients, as the primary target customers (Arendt and Dal Bello, 2008). The utilization of rice grain in rice flour production and rice-based products is expected to continuously increase (Araki *et al.,* 2016).

Rice flour can be obtained from complete rice grains, but it is usually manufactured from broken rice, which is the by-product obtained during milled rice processing (Rosniyana *et al.,* 2016). The processing of rice flour has three different methods, namely, dry, wet, and semi-dry grinding (Hui, 2008; Asmeda *et al.,* 2016). All grinding methods stated are the standard size reduction processes used in rice flour production (Chiang and Yeh, 2002). In Malaysia, the most common grinding method applied is wet grinding, especially for rice flour that is utilized in noodle manufacturing (Yeh, 2004). The dry milling method is simple and straightforward, incurs less energy consumption, and does not generate wastewater (Asmeda *et al.,* 2016; Jan *et al.,* 2017). Unlike the dry milling method, wet grinding requires a conditioning process to keep the internal structure of rice kernels better, thus easing the subsequent milling process (Kim, 2013). Moreover, wet milling incurs a high cost, is labour intensive for flour production, and produces a substantial amount of wastewater (Yeh, 2004). In general, the most common milling machines typically utilized in flour production are a hammer, pin, roller, and disc mill (Jan *et al.,* 2017).

The properties of starch within rice flour are generally affected by different factors, thus generating rice flour with various physicochemical and functional properties (Rosniyana *et al.,* 2016; Hasmadi *et al.,* 2020). The performance and quality of rice flour may also vary depending on the processing methods utilized during its production, heredity, and environmental conditions during the period of plant growth (Patindol *et al.,* 2015; Asmeda *et al.,* 2016; Rosniyana *et al.,* 2016). Other factors such as morphological properties, damaged starch, amylose and amylopectin content, mineral content, and amylopectin chain length distribution also can influence the starch properties within rice flour (Anugrahati *et al.,* 2017). Among the physicochemical attributes, amylose is the primary determinant that affects the quality of final baked products (Han, 2012). In general, the amylose content of rice can control the volume expansion of yeast-leavened rice bread (Kum, 1998). According to Han *et al.* (2012), intermediate amylose content and lower water absorption are the leading parameters of rice bread flour quality. Therefore, the factors that could influence the performance of rice flour should be studied to optimize the final product quality (Olewnik *et al.,* 2011).

In this present article, the factors affecting the properties of rice flour are reviewed. Factors that will be discussed in this article include environmental conditions in terms of temperature extreme and soil conditions, milling methods, amylose and amylopectin composition, as well as endogenous protein, and lipid content.

2. Factors affecting the properties of rice flour

2.1 Environmental conditions

In the agricultural sector, environmental conditions are the essential factors that should be focused on because of their possible influence on starch properties (Bao *et al.,* 2004; Asmeda *et al.,* 2016). Generally, researchers agree that environmental conditions will become unpredictable in the future (Lobell *et al.,* 2012; IPCC, 2013; Jing *et al.,* 2016) and thus deteriorate the quality and performance of grain and flour (Hatfield *et al.,* 2011). The two distinct major factors that commonly affect the growth and quality of crops are the surrounding temperature of the cultivation area and soil nutrient composition (Beckles and Thitisaksakul, 2014; Patindol *et al.,* 2015).

2.1.1 Temperature extreme

Temperature is a vital factor in agricultural production (Beckles and Thitisaksakul, 2014). A high growth temperature of approximately 35°C may result in a detrimental effect on the growth and development of rice grain and grain quality (Tian *et al.,* 2007; Lin *et al.,* 2010; Shi *et al.,* 2018). The effect of temperature incidence on rice cultivation has received considerable critical attention because the prediction of air temperature could elevate from 1.8°C to 4.5°C by the end of the century (Shakun *et al.,* 2012; Glaubitz *et al.,* 2014). Dang and Copeland (2004) and Aboubacar *et al.* (2006) reported that amylose content is high within rice flour made from rice cultivated at cold temperatures compared with that in high growth temperatures. Similarly, Beckles and Thitisaksakul (2014) found that elevated temperature can reduce the amylose content by approximately 20% within the rice and may produce rice flour with lower amylose content. This phenomenon may occur because elevated temperature reduces the gene expression that forms amylose–granule–bound starch synthase, which causes a decrease in the concentration of amylose (Larkin and Park, 1999; Ahmed *et al.,* 2007).

In addition, most rice cultivars under heat stress might undergo an alteration in amylopectin glucan chain-length distribution and may cause the rice grain to turn chalky (Beckles and Thitisaksakul, 2014). In general, the chalky part of rice grains indicates the loosely packed starch granules (Araki *et al.,* 2016). Typically, chalky rice grains possess low grain hardness and produce rice flour with fine particle size, high water absorption properties, and increased granule swelling power (Ashida *et al.,* 2009). Ashida *et al.* (2014) reported that the specific loaf volume of bread made from pin-milled chalky rice was equivalent to the bread made from enzyme-treatment milled translucent white rice. However, information regarding the effect of chalky rice grain in the manufacturing of rice flour and the development of gluten-free bakery products remains lacking. Hence, further studies are expected in the future, because chalky rice can be utilized in the development of gluten-free bakery products because of its fine particle size (Ashida *et al.,* 2010) and low starch damage (Ashida *et al.,* 2009) after the milling process.

Aside from heat stress, low surrounding temperature could also affect rice flour quality. In general, rice flour developed from rice cultivated in controlled low-temperature environments, cool field locations, and cold season tends to possess high amylose content compared with that under warm growth temperatures (Dang and Copeland, 2004). The previous study performed by Beckles and Thitisaksakul (2014) revealed that rice cultivars comprise of Doongara, Langi and Kyeema grew in the 1999/2000 season, which was the coolest (28.1°C - 13.9°C) among the three seasons containing high amylose content which are 29.2%, 19.1% and 19.4%, respectively. Whereas the amylose content for all three cultivars cultivated in the 1998/1999 season (28.6 - 14.2°C) and 2000/2001 season (29.4 - 14.6°C) are 28.1%, 18.5%, 19.2% and 27.3%, 17.2% and 18.1%, respectively. According to Aboubacar *et al.* (2006), the gelatinization temperature in the aspects of the onset (T_o), peak (T_p), and conclusion (T_c) temperature of rice varieties grown in cool temperature areas are lower ranging from 66 - 68°C for T_o, 73 -75°C for T_p and 82 - 85°C for T_c temperature, respectively compared to rice cultivars grown in high temperature. Besides, in conjunction with the increased amylose content of rice cultivated in cooler temperatures, Dang and Copeland (2004) reported that rice flour made from rice grown in considerably cooler temperatures exhibited lower peak viscosity and higher setback than rice grown in a warmer temperature. In general, peak viscosity is associated with the water-binding capacity, and the disintegration of starch granules is often related to the quality of the final products (Tran *et al.,* 2001). Meanwhile, the setback value conveys the increase in viscosity starting from the minimum to the final value and is generally related to the texture of end products. A higher setback value is associated with the swelling power as well as related to the amylose content of the rice flour (Martin and Smith, 1995). Overall, only a few studies have focused on the effect of environmental temperature on rice flour quality; thus, the information associated with this factor is still scarce.

2.1.2 Soil conditions

Rice, the primary staple food for Asian people, is cultivated over a broad range of environmental and soil conditions. Essentially, depending on the hydrology of the cultivation area, the environment cultivation for rice can be divided into four conditions, such as precisely irrigated lowland, rainfed lowland rice, flood-prone rice, and upland rice (Bouman *et al.,* 2007). In general, the yield and quality of rice grown in a rainfed rice field are the most vulnerable during drought because of the absence of rainfall or irrigation that negatively affects crops. Limited information is available about the effect of drought stress on rice, which can affect the subsequent flour properties produced from those rice grains (Gunaratne *et al.,* 2011). Water deficiency during the growth period can reduce the amylose content of rice and rice flour (Cheng *et al.,* 2003; Liu *et al.,* 2010; Gunaratne *et al.,* 2011). Furthermore, as noted by Beckles and Thitisaksakul (2014), water stress can affect starch functionality properties, especially pasting properties. Rice flour from cultivars exposed to water stress exhibits rapid swelling, a decrease in onset pasting temperature, an increase in peak viscosity, and granular breakdown (Gunaratne *et al.,* 2011). The granular breakdown usually occurs because of the high swelling power of starch granules caused by heat stress, thus causing the starch granules to disintegrate under high temperature and shear forces, leading to the breakdown of granules (Kaur *et al.,* 2007; Gunaratne *et al.,* 2011).

Aside from water deficit, soil salinity can also influence the quality of rice flour produced from rice exposed to salinity stress. Salinity stress is a condition in which soluble salts accumulate in the soil to an extent, causing a detrimental effect on plant growth (Srivastava *et al.,* 2019). Saline soil is typically the reservoir of numerous soluble salts, such as calcium, magnesium, sodium, and anions such as sulfate, chloride, and bicarbonate with an exceptional amount of potassium, carbonate, and nitrate (Ghosh and Gantait, 2016). In an investigation on the effect of salinity stress on rice flour quality, Baxter *et al.* (2011) found that the pasting properties of rice flour are affected by saline stress. This finding was obtained possibly because salinity stress can alter the endosperm protein level and composition, thus modifying the pasting properties of rice flour. Thitisaksakul *et al.* (2015) also reported that the upsurge of endosperm protein level, glutelin, and prolamin was significantly enhanced in rice grown under saline treatment, and a significant influence was observed on glutelin than prolamin. Overall, based on reading sources' availability, the data on salinity stress towards rice flour quality is still limited.

2.2 Milling method

Two common milling methods will be discussed in the present article, which is the dry and wet milling processes. In general, dry milling is a simple method done under dry conditions, does not require water during rice grain milling and produces zero wastewater (Ngamnikom and Songsermpong, 2011; Asmeda *et al.,* 2016). On the contrary, water utilization is necessary for the wet-milling method because the soaking step is involved, which eventually delivers softening effect to the rice kernels, subsequently easing the milling process (Mo *et al.,* 2013). The milling process can affect the physicochemical properties of flour (Lee *et al.,* 2019; Yan *et al.,* 2020) and determine the quality of the final product (Zhang *et al.,* 2020). Three distinct sources have examined the difference in the quality of wet-milled and dry-milled rice flour. In the study by Wu *et al.* (2019), the quality and performance of three types of milled-rice flour prepared with different milling methods, such as wet and dry milling (e.g., cyclone milling and ultrafine milling), have been investigated. They found that wet-milled flour possesses the most suitable starch properties to produce the best rice bread quality and fulfil consumer expectations. Likewise, Rosniyana *et al.* (2016) and Zhang *et al.* (2020) agreed with the finding of Wu *et al.* (2019), where the flour produced with the wet milling method successfully produced good flour quality, whereas dry-milled flour increased the damaged starch content, thus affecting the solid loss and oil and water holding capacity, resulting in products with unacceptable properties. However, although wet milling can produce good-quality flour, this method is not cost-effective and produces a substantial amount of waste compared with dry milling (Tong *et al.,* 2017).

In general, almost every paper that focused on the milling method towards flour quality includes the effect relating to damaged starch content and particle distribution. The wet-milling method could produce good flour quality compared with the dry-milling method (Ahmad *et al.,* 2016; Rosniyana *et al.,* 2016; Wu *et al.,* 2019; Zhang *et al.,* 2020). This finding was obtained mainly because the wet-milling method can produce rice flour with lower damaged starch content. According to Asmeda *et al.* (2016), damaged starch is produced during the milling process because of frictional heat and mechanical force. Unlike the dry milling method, the wet milling method involves a soaking rice kernel process (Lu and Collado, 2019). Consequently, it contributes to a softening effect, thereby easing the milling process and producing less damaged starch also fine particles than the dry milling method (Ngamnikom and Songsermpong, 2011; Mo *et al.,* 2013). However, the statement regarding particle distribution is contradictory when the wet-milling method is compared with the ultrafine milling method, which is also a dry-milling process. Wu *et al.* (2019) found that the ultrafine milling method produces more fine flour particles than the wet milling method, but the damaged starch produced by the ultrafine milling technique is higher than the wet milling method because of severe processing. Chen *et al.* (2003) and Dhital *et al.* (2011) have reported that the damaged starch granules are complemented by the destruction of crystalline structures and lower gelatinization temperature than made the starch intact. Furthermore, the highly damaged starch content led to high water absorption properties within the flour (Naganuma, 2003).

Interestingly, rice flour dough's rheological properties and the quality of the final products made from wet-milled and dry-milled flour were observed. In the study conducted by Heo *et al.* (2013), dough made from dry-milled flour is more resistant to extension than wet-milled flour. The results agree with Kumar *et al.* (2008), in which authors found that dough made from dry-milled rice flour is stiffer and requires more force to elongate than wet-milled rice flour. Moreover, an analysis of gel properties of rice flour milled with different methods has shown that the gel hardness in wet -milled flour is significantly higher than that in ultrafine-milled flour (dry milling; Wu *et al.,* 2019). In general, factors such as damaged starch, the structural properties of rice granules and composition, and the structure of starch could affect the gel hardness of rice flour (Wang *et al.,* 2010). The high content of damaged starch within the flour may lead to the formation of a weak gel after gelatinization, thus forming weak network structures that are not strong enough to support rice flour bread (Wu *et al.,* 2019; Hasmadi, 2021). Overall, based on a few research that mainly investigated the effect of different milling methods, wet-milled flour has the potential quality that can produce good gluten-free rice bread. However, the utilization of dry-milled flour is acceptable in baked because it produces zero waste, but further research is required to improve the quality of the end products.

2.3 Amylose and amylopectin composition

Starch is the main ingredient in rice flour. Two major polysaccharides, amylose and amylopectin, are the primary component of starch granules (Bertoft, 2017). Essentially, amylose is a linear molecule that comprises α-(1,4)-linked glucose units with few branches, while amylopectin is a branched molecule with linear chains of α-(1,4)-linked glucose units with α-(1,6)-linked branches (Aoki *et al.,* 2012). In general, granule-bound starch synthase I is responsible for amylose synthesis (Hanashiro *et al.,* 2008). By contrast, the synthesis of amylopectin is controlled by soluble starch synthase, starch branching enzymes, and starch debranching enzymes (Nakamura, 2002).

Rice containing lower amylose content ranging between 6% to 10% has been recognized with high stickiness when cooked as boiled rice (Araki *et al.,* 2016). Similarly, a product made from rice flour containing low amylose content tends to exhibit dampness, softness, chewiness (Kraithong and Rawdkuen, 2019), and low specific volume, especially in the development of gluten-free bread (Araki *et al.,* 2016). Conversely, rice flour with high amylose content (>30%) offers crispness and firmness to the product texture because of the formation of the three-dimensional network (Wang *et al.,* 2016). It also presents a perfect shape; nevertheless, it tends to stale faster due to the retrogradation process (Aoki *et al.,* 2012). Takahashi *et al.* (2009) noted that rice flour contains medium amylose content ranging from 16% to 20%, potentially producing gluten-free bread that is chewy and has mild softness. Aside from amylose content, Aoki *et al.* (2012) found that bread made from rice flour containing a higher fraction of amylopectin long-chain shows a harder texture than the bread developed from rice flour containing a lower fraction of long amylopectin chains, notwithstanding the minor difference in amylose contents. Therefore, rice flour with moderate amylose content is suitable for developing rice flour compared with high and low amylose content because of its unfavourable shape and texture. On the other hand, another study by Roman *et al.* (2020), for the first time, found that the amylose length within rice flour also plays an essential role in affecting the quality of gluten-free rice bread mainly on the crumb texture. The reason is that Roman *et al.* (2020) reported that rice flour produced from two different rice cultivars, Basmati and Bomba, with amylose lengths of 699 and 978, respectively, developed gluten-free bread that possesses significantly difference in the aspect of hardness, which Basmati produced harder crumb texture than Bomba, without having any significant differences in the aspects of amylose content. Hence, the authors concluded that amylose length is a crucial factor influencing the quality of rice bread.

Amylose and amylopectin can significantly influence the physicochemical properties of rice flour. In the study conducted by Yu *et al.* (2012), rice flour's swelling capacity is influenced by amylopectin content. This finding is supported by the result obtained by Singh *et al.* (2006), in which swelling power is associated with amylopectin content. Moreover, Kemashalini *et al.* (2018) discovered that rice flour's swelling capacity declines with the rise of amylose content because the linear and long polymer chain of amylose consequently acts as an inhibitor of the starch swelling process. Aside from swelling capacity, amylose and amylopectin can affect the gelatinization temperature and pasting properties of rice flour. Gelatinization temperature is directly proportional to the amylose content, but it exhibits a negative correlation with the amylopectin short chains (DP 6-12) and a positive correlation with amylopectin long branch chains (DP $\geq$ 37) (Park *et al.,* 2007). In general, the short branch chains of amylopectin destabilize the crystalline lamellar structure, while long branch chains of amylopectin can form longer double helices, leading to a higher temperature in order to be entirely dissociated (Chung *et al.,* 2011). According to Aoki *et al.* (2012), gluten-free bread made from rice flour with lower gelatinization temperature might result in softer and desirable properties. Therefore, amylose and amylopectin are considered essential determinants of rice flour performance and the quality of final products.

2.4 Endogenous protein and lipid content

Various rice types, rice grain cultivation, and rice flour processing could affect the chemical composition of rice flour, including carbohydrates, proteins, and lipids (Falade and Christopher, 2015). The majority of studies focused on the effect of carbohydrates, including amylose and amylopectin, on the performance of rice flour (Wang *et al.,* 2016). Endogenous protein and lipid can also influence rice flour properties (Putseys *et al.,* 2010; Parada and Santos, 2016). Generally, rice contains 2–5% of protein, predominantly glutelins (Kraithong and Rawdkuen, 2019; Graziano *et al.,* 2020), whereas the lipid content is 0.3–3.9%, and the main lipid content comprises triglyceride, together with a small number of phospholipids, glycolipids, and waxes (Hamaker, 2007). Both lipid and protein can be associated with amylose, in which the latter forms an amylose–lipid and amylose–protein complex that can affect the properties and attributes of the end-products (Bhandari *et al.,* 2013; Parada and Santos, 2016).

Granule swelling is initiated when rice flour is heated with excess water. Generally, the crystalline structure of starch molecules disassociates, subsequently allowing water molecules to be bound to the hydroxyl groups by hydrogen bonding, resulting in swelling of starch granules (Ye *et al.,* 2018). Several researchers have reported that protein and lipid can affect the swelling properties of rice flour (BeMiller and Whistler, 2009; Chinma *et al.,* 2015; Ye *et al.,* 2018; Kraithong and Rawdkuen, 2019). This property can be explained by the presence of protein matrices that enclose the starch granules, and these matrices might impede the absorption and hydration of water, thus reducing the swelling of starch granules (Wongdechsarekul and Kongkiattikajorn, 2009). Moreover, the decline in swelling properties together with water absorption index is triggered by amylose–protein and amylose–lipid complexes, which can interrupt the water absorption because of the presence of linear structure and lipophilic parts (Ali *et al.,* 2016) and decrease the hydrophilic parts within rice flour (BeMiller and Whistler, 2009). The complexes between amylose to protein or lipid also decreased the water solubility index (Kaur and Singh, 2000; Kraithong and Rawdkuen, 2019). Xie *et al.* (2008) and Tong *et al.* (2015) justified that this phenomenon could be caused by the presence of complexes that hinder water penetration to retain the integrity of starch granules which will decrease the leaching of amylose.

Another aspect of rice flour that is possibly influenced by proteins and lipids is the gelatinization temperature. In the study performed by Ye *et al.* (2018), rice flour with low lipid and protein content is more vulnerable to gelatinization. Interestingly, this result was consistent with the study carried out by Bandhari *et al.* (2013) and Kraithong and Rawdkuen (2019). Both studies revealed that the gelatinization temperature is affected by the lipid and protein contents primarily because of the ability to form complexes with amylose that will interrupt the water hydration, consequently increasing the gelatinization temperature. Additionally, Fradinho and Raymundo (2019) reported the same finding, in which the amylose–lipid complex generally restricts the starch granules from expansion during the gelation process and delays the occurrence of retrogradation of the product. In general, the delay of retrogradation or staling rate of bread can be initiated by the formation of complexes, and this process could damage the hydrogen bond, and consequently slow down the rearrangement of starch molecules (Siriamornpun *et al.,* 2016). Therefore, in the aspect of retrogradation, the utilization of rice flour with a considerably high amount of protein and lipid could enhance the shelf life of the product. Table 1 represents the factors affecting the properties of rice flour.

3. Conclusion

The properties of rice flour depending on the starch structure, which substantially determines its performance in downstream applications. In the present articles, previous studies have shown that factors such as environmental conditions, milling method, amylose and amylopectin composition and endogenous protein and lipid content could influence the performance of rice flour. Environmental conditions such as extreme temperature could influence the amylose content and amylopectin chain length, affecting rice flour's functional and thermal properties, mainly on the gelatinization temperature and pasting properties (peak viscosity and setback value). However, instead of temperature extreme, soil conditions are another environmental factor affecting the rice flour starch properties. In general, water deficiency and salinity stress during the rice growth period will affect the pasting properties, reduce the amylose content, increase the swelling rate of starch granules, and alter the endosperm protein level modifying the rice flour pasting properties, respectively. Besides, another essential parameter that could influence rice flour characteristics is the milling method. Generally, wet-milled rice flour has been found to produce rice flour applicable to the development of gluten-free rice bread more than dry-milled rice flour. On the other hand, the major polysaccharide within rice flour, amylose and amylopectin, also play a vital role in affecting the performance of rice flour. Different amylose content and amylopectin chain length level will result in the different textures of the final product. Besides, both compositions significantly influence the physicochemical attributes of rice flour, especially in swelling capacity, gelatinization temperature and pasting properties. Endogenous protein and lipid content can be associated with amylose, which forms complexes called amylose-protein and amylose-lipid. Consequently, affecting swelling properties, water solubility index, gelatinization temperature, and well as retrogradation rate.

Therefore, a good understanding of the factors that could influence the properties of rice flour is crucial for developing a novel rice-based product because it can help predict and control the outcome of end-products. However, a huge research gap can be considered in determining the factors that affect the properties of rice flour, especially in the aspects of environmental conditions, because the properties of rice flour could be heavily modulated when rice encounters extreme environmental stress during the growing period.

Conflict of interest

The authors have declared no conflicts of interest for this article.

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Table 1. Factors affecting the properties of rice flour

Parameter	Description	References
Environmental conditions	***Temperature Extreme***	
	High temperature	
	• Reduced approximately 20% of the rice's amylose content and subsequently produced rice flour with lower amylose content.	Beckles and Thitisaksakul (2014)
	• An elevated temperature may cause rice grain to turn chalky leading to rice flour that exhibits fine particle size, high water absorption properties, and increased granule swelling power.	Ashida *et al.* (2009); Beckles and Thitisaksakul (2014)
	Low temperature	
	• Caused rice flour to possess high amylose content compared to rice flour made from rice grain cultivated at high temperature.	Dang and Copeland (2004); Beckles and Thitisaksakul (2014)
	• Reduced the gelatinisation and pasting temperature of rice flour.	Aboubacar *et al.* (2006)
	Soil Conditions	
	Water stress	
	• Reduced the amylose content of rice flour.	Cheng *et al.* (2003); Liu *et al*. (2010); Gunaratne *et al.* (2011)
	• Increased the swelling properties, peak viscosity and granular breakdown and decreased the onset of pasting temperature.	Gunaratne *et al.* (2011); Beckles and Thitisaksakul (2014)
	Soil salinity	
	• Salinity stress can alter the rice endosperm protein level and composition, causing alteration to the pasting properties of rice flour.	Baxter *et al.* (2011)
Milling Method	**Wet milling method**	
	• Produced best rice bread quality.	Wu *et al*. (2019)
	• Produced good quality rice flour with lower damages starch content.	Ahmed *et al.* (2016); Rosniyana *et al.,* Wu *et al*. (2019); Zhang *et al*. (2020)
	• Produced fine particles rice flour.	Ngamnikom and Songsermpong (2011); Mo *et al*. (2013)
	• Gel hardness properties of wet-milled rice flour are higher compared to dry-milled rice flour.	Wu *et al*. (2019)
	Dry milling method	
	• Increased the damages starch content, which influences the solid loss, oil and water holding capacity and unacceptable final products	Rosniyana *et al*. (2016); Wu *et al*. (2019); Zhang *et al*. (2020)
	• High damage starch content caused destruction to the crystalline structures, lower gelatinisation temperature and increased the water absorption properties of flour.	Chen *et al*. (2003); Naganuma (2003); Dhital *et al*. (2011)
	• Produced dough that is more resistant to extension.	Heo *et al*. (2013)
	• Made dough stiffer and required more force to elongate the dough.	Kumar *et al.* (2008)
	• High damage starch content leads to the formation of the soft gel after gelatinisation subsequently forming weak network structures that are not strong to support bread.	Wu *et al.* (2019)
Amylose and Amylopectin	**Amylose**	
	• Low amylose content rice flour tends to exhibit dampness, softness, chewiness and low specific volume rice bread.	Araki *et al.* (2016); Kraithong and Rawdkuen (2019)
	• High amylose content offers crispness, firmness, formation of the three-dimensional network, perfect shape, and stale faster due to the retrogradation process.	Aoki *et al.* (2012); Wang *et al*. (2016)
	• Medium amylose content produced gluten-free bread that is chewy and has mild softness.	
	• Amylose length within rice flour is capable of affecting the texture of rice bread.	Takahashi *et al.* (2009)
	• Increased amylose content leads to lower swelling capacity properties.	Roman *et al*. (2020)
	• Gelatinisation temperature has been shown to increase with the upsurged of amylose content.	Park *et al*. (2007); Kemashalini *et al*. (2018)

Table 1 (Cont.). Factors affecting the properties of rice flour

Parameter	Description	References
Amylose and Amylopectin	**Amylopectin**	
	• A higher fraction of amylopectin long-chain shows a more rigid texture than bread made from rice flour with a lower fraction of long-chain amylopectin.	Aoki *et al*. (2012)
	• Amylopectin content influenced the swelling properties of rice flour.	Singh *et al*. (2006); Yu et al. (2012)
	• Amylopectin long branch chains have a positive correlation with the gelatinisation temperature of flour.	Park *et al*. (2007)
Endogenous Protein and Lipid Content	• High protein matrixes might impede the absorption and hydration of water leading to low swelling capacity.	Wongdechsarekul and Kongkiattikajorn (2009)
	• Initiate the formation of amylose-protein and amylose-lipid complexes that decreased water absorption.	Ali *et al*. (2016)
	• The formation of complexes decreased the water solubility index.	Kaur and Singh (2000); Kraithong and Rawdkuen (2019)
	• Rice flour with low lipid and protein content is more vulnerable to gelatinisation.	Bandhari *et al*. (2013); Ye *et al*. (2018); Kraithong and Rawdkuen, (2019)
	• The formation of complexes delayed the occurrence of retrogradation of the end-product.	Siriamornpun *et al*. (2016); Fradinho and Raymundo (2019)

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