International Food Research Journal 29(4): 909 - 917 (August 2022)
Journal homepage: *http://www.ifrj.upm.edu.my*

Comparison of spontaneous and *ragi* fermentations on the physicochemical and functional properties of cereal flours

[1]*Ambarsari, I., [2]Qanytah, [3]Santoso, S. B., [1]Oktaningrum, G. N. and [1]Wulanjari, M. E.

[1]*Central Java Assessment Institute for Agricultural Technology, Bukit Tegalepek, Sidomulyo, PO Box 101, Ungaran 50501, Central Java, Indonesia*
[2]*Indonesian Centre for Agricultural Post Harvest Research and Development, Jl. Tentara Pelajar No. 12, Cimanggu Agricultural Research Campus, Bogor 16111, West Java, Indonesia*
[3]*Indonesian Cereal Research Institute, Jl. Dr. Ratulangi No. 274, PO Box 173, Maros 90514, South Sulawesi, Indonesia*

Article history

Received:
17 July 2021
Received in revised form:
13 November 2021
Accepted:
23 December 2021

Keywords

flour,
cereals,
ragi fermentation,
spontaneous fermentation

Abstract

Spontaneous and *ragi* fermentations are the most common methods in producing traditional fermented foods in Indonesia. The present work aimed to compare the impacts of spontaneous and *ragi* fermentations on cereal flour properties. Three kinds of cereal, namely whole sorghum, waxy coix, and white maize were processed into flours through spontaneous fermentation, *ragi* fermentation, and without fermentation (control). Fermentation methods were adopted from the Indonesian traditional processing methods. Cereal grains were immersed for 72 h in distilled water (1:2 w/v) for spontaneous fermentation, and in 1% *ragi tapai* solution (1:2 w/v) for *ragi* fermentation. Meanwhile, native flour (without fermentation) was produced by grounding and sieving the cereal grains. Results showed that both fermentation techniques significantly altered the physical properties of cereal flours, as indicated by the increase in lightness index and decrease in water-binding capacity and viscosity. However, cereal flours' chemical and functional properties remain unchanged during fermentation, except for lipid and amylose. Spontaneous fermentation significantly resulted in the lowest lipid content of cereal flours, while *ragi* fermentation resulted in the lowest amylose content of cereal flours. Sorghum flour generally showed better nutritional properties among the examined cereal flours, especially lipid, protein, and dietary fibre. Meanwhile, waxy coix and white maize flours had the highest folate.

DOI
https://doi.org/10.47836/ifrj.29.4.18

Introduction

In recent decades, researchers have revealed that the consumption of gluten-containing food products was strongly related to celiac disease, wheat allergies, dermatitis herpetiformis, and other gluten-related disorders (Moroni *et al.*, 2010; Capriles *et al.*, 2016; Rocchetti *et al.*, 2019). This, and increased consumer awareness, thus led both the food industries and researchers to exploring alternatives for gluten-free flours (Rocchetti *et al.*, 2019).

The use of non-wheat cereal grains such as sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.), job's tear (*Coix lacryma-jobi* L.), and other pseudocereals has potential to obtain gluten-free flours. These cereals are relatively inexpensive and widely available, and better known as animal feeds rather than human foods. As food sources, these gluten-free cereals are rich in starches, proteins, lipids, vitamins, minerals, dietary fibres, polyphenols, and other bioactive compounds that exert pharmacological functions and benefits towards human health (Kulamarva *et al.*, 2009; Marengo *et al.*, 2015; Xu *et al.*, 2018).

However, some nutritional deficiency issues have often been associated with gluten-free-based products as compared to wheat-based products (Capriles *et al.*, 2016; Rocchetti *et al.*, 2019). In this circumstance, fermentation could serve as a strategy to improve gluten-free cereal products' quality. Fermentation is one of the oldest ways to transform cereals into edible products (Bationo *et al.*, 2020). Several studies have revealed that fermentation can enrich the nutritional values and sensory properties,

*Corresponding author.
Email: indrie.amb@gmail.com

and remove undesirable compounds in cereal products (Aktaş and Akın, 2020; Väkeväinen *et al.*, 2020).

Among fermentation techniques, spontaneous and *ragi* fermentations are interesting to be evaluated in-depth, since these are commonly used in producing traditional fermented foods in Indonesia. Spontaneous fermentation is widely applied in developing countries since it is convenient and does not require many processing facilities. Meanwhile, the application of *ragi* as a starter culture for fermented products is prevalent in Indonesia and Malaysia. *Ragi* is a dry starter prepared from a mixture of rice flour, spices, and water or sugar cane juice (Azmi *et al.*, 2010). Dry *ragi tapai* starter contains a mixture of microorganisms such as yeasts (*Saccharomyces*), moulds (*Mucor*, *Rhizopus*, or *Amylomyces*), and bacteria (Azmi *et al.*, 2010; Law *et al.*, 2011; Nursiwi *et al.*, 2018).

To the best of our knowledge, no studies have directly compared the impacts of spontaneous and *ragi* fermentations on cereal flour properties. Therefore, the present work intended to compare spontaneous and *ragi* fermentations' effectiveness in enhancing cereal flours' characteristics. We expect better insight into proper and compatible fermentation techniques which might extend the cereal flour applications and improve the end-product quality.

Materials and methods

Materials

Three types of cereals were investigated in the present work, namely white sorghum, waxy coix, and white maize cv. Srikandi Putih. These grain varieties were obtained locally from farmers in Central Java, Indonesia. In addition, *ragi tape* NKL (Na Kok Liong Co., Surakarta, Indonesia) was purchased from a local traditional market.

Sample preparation

The white sorghum was used as whole grain, while waxy coix and white maize were decorticated using an abrasive polishing machine to produce refined grains. Each cereal grain was divided into three treatments, namely without fermentation (control), spontaneous fermentation, and *ragi* fermentation.

Cereal grains were immersed in the distilled water at a ratio of 1:2 w/v for spontaneous fermentation, and soaked in the 1% yeast (*ragi*) solution of 1:2 w/v for *ragi* fermentation (Syahputri and Wardani, 2015; Aini *et al.*, 2016). After 72 h, all fermented grains were washed and drained to remove the excess water. Next, fermented grains were dried in the cabinet dryer (50 ± 5°C) for 24 h, then milled and sieved into 80 mesh (British Standard) to obtain the flours. Meanwhile, grains were cleaned, sorted, ground, and sieved to 80 mesh particle sizes to produce native flour (without fermentation). Finally, fermented and unfermented flours were packed in polyethylene (PE) bags, and stored in an airtight container until further analyses.

Data collection and analysis

Determination of water-binding capacity (WBC) was performed using a method described by Sandhu *et al.* (2008). The viscosity was carried out using a micro visco-amylograph (Brabender OHG, Germany) (Mariotti *et al.*, 2006), while colour was measured by spectrocolorimeter (Hunter Associates Lab., Inc., Reston, VA, USA) (Aboubakar *et al.*, 2008). The chemical properties such as moisture, lipid, protein, and carbohydrate were determined using a method proposed by the American Association of Cereal Chemists (AACC, 2000). Meanwhile, the measurement of functional properties included amylose (Nwokocha and Williams, 2011), total folate (Kariluoto and Piironen, 2009), and dietary fibre (Asp *et al.*, 1983). Each variable of chemical and functional attributes was represented on a dry basis (db).

Statistical analysis

A completely randomised factorial design, in which cereal types and fermentation methods were considered factors, was employed in the present work. Each treatment consisted of three replications. Data were examined using two-way ANOVA. Further analysis using Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$ was carried out to determine the differences between treatments. All statistical analyses were performed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA).

Results and discussion

Physical characteristics

Results showed that fermentation significantly decreased the WBC value of cereal flours (Table 1). This is consistent with an earlier study on sorghum flour (Elkhalifa *et al.*, 2005). However, there was no significant difference in WBC value between spontaneous and *ragi* fermented flours. Among all cereal types, white maize flours had the highest WBC value. Using flour with high WBC in bread formulation would help the dough to have sufficient viscoelastic properties, and to increase the specific bread volume (Lestari *et al.*, 2019).

Table 1. Effects of different fermentation methods on the WBC and viscosity of the cereal flours.

Cereal type	Fermentation method	WBC (%)	Viscosity (BU)
Whole sorghum	Native (control)	1.40 ± 0.00^{a}	780.0 ± 10.0^{a}
	Spontaneous	1.33 ± 0.10^{b}	603.3 ± 12.7^{b}
	Ragi	1.33 ± 0.06^{b}	575.0 ± 17.0^{b}
Waxy coix	Native (control)	1.60 ± 0.18^{a}	1395.0 ± 15.0^{c}
	Spontaneous	1.20 ± 0.20^{b}	943.3 ± 40.4^{d}
	Ragi	1.37 ± 0.04^{b}	965.0 ± 12.1^{d}
White maize	Native (control)	2.03 ± 0.15^{c}	1545 ± 25.0^{c}
	Spontaneous	1.87 ± 0.15^{d}	1080 ± 17.9^{d}
	Ragi	1.70 ± 0.10^{d}	951.7 ± 40.4^{d}
p-value	Cereal type	0.000	0.000
	Fermentation method	0.015	0.000
	Cereal × Fermentation	0.017	0.335

Means followed by different lowercase superscripts within columns are significantly different ($p \leq 0.05$).

Fermentation also influenced the viscosity of the cereal flours. The viscosity of fermented cereal flours was significantly lower than native flour. A similar occurrence was reported in fermented wheat starch (Zhao *et al.*, 2019), fermented rice flour (Lu *et al.*, 2005), and fermented maize flour (Ntso *et al.*, 2017). It was presumed that fermentation decreased the molecular weight and changed the starch's molecular structure, culminating in the viscosity decrease (Zhao *et al.*, 2019). However, there was no significant difference in the viscosity values between spontaneous and *ragi* fermented flours. Among all cereals samples, whole sorghum flour had the lowest viscosity. This might be related to the existence of brans in the whole sorghum flour. Another study in fermented cereal-based products also reported that higher amounts of brans might decrease the viscosity values of flours (Aktaş and Akın, 2020).

The colour characteristics of the cereal flours are presented in Table 2. Results revealed that whole sorghum flour was darker (low L^* value) than the other two cereal flours. The dark colour of sorghum flour might be associated with the existence of sorghum bran which was responsible for lignin enhancement (Aktaş and Akın, 2020). However, there was an intensification of yellow colour (b^* value) on sorghum flours. This intense yellow colour indicated

Table 2. Effects of different fermentation methods on the colour index of the cereal flours.

Cereal type	Fermentation method	L^*	a^*	b^*
Whole sorghum	Native (control)	62.44 ± 1.16^{a}	17.16 ± 0.05^{a}	13.09 ± 0.19^{a}
	Spontaneous	68.25 ± 4.53^{b}	15.52 ± 0.67^{a}	13.21 ± 1.04^{a}
	Ragi	68.08 ± 3.13^{b}	14.47 ± 4.75^{a}	12.46 ± 3.00^{a}
Waxy coix	Native (control)	75.82 ± 0.20^{c}	11.32 ± 0.13^{a}	9.36 ± 0.24^{b}
	Spontaneous	80.84 ± 2.15^{d}	15.65 ± 2.28^{a}	10.31 ± 0.65^{b}
	Ragi	78.26 ± 0.57^{d}	14.19 ± 1.11^{a}	10.19 ± 0.87^{b}
White maize	Native (control)	75.60 ± 0.32^{c}	13.99 ± 0.91^{a}	11.23 ± 0.07^{b}
	Spontaneous	77.13 ± 1.73^{d}	12.94 ± 0.93^{a}	10.37 ± 0.42^{b}
	Ragi	78.76 ± 2.78^{d}	15.40 ± 1.52^{a}	11.11 ± 1.35^{b}
p-value	Cereal type	0.000	0.089	0.000
	Fermentation method	0.002	0.788	0.993
	Cereal × Fermentation	0.353	0.045	0.635

Means followed by different lowercase superscripts within columns are significantly different ($p \leq 0.05$).

higher availability of some pigment components such as carotenoid in sorghum flours.

As expected, the lightness (L*) value of fermented flours was higher than the native flour. However, there was no significant difference in the L* values between spontaneous with *ragi* fermented flours. No significant difference was detected for a* and b* values among native and fermented cereal flours, which indicated that pigment compounds in all flours remained constant during fermentation. The slight changes in fermented flours' colour could probably be due to a restricted starch breakdown during fermentation (Marengo *et al.,* 2015).

Chemical characteristics

Table 3 presents the chemical properties of sorghum, coix, and maize flours produced from different fermentation methods. Each cereal type had different moisture content. This indicated that different species of cereals would affect the moisture content of the flour produced. However, there was no significant difference in the moisture contents of spontaneous and *ragi* fermented cereal flours.

Table 3. Effects of different fermentation methods on the chemical characteristics of the cereal flours.

Cereal type	Fermentation method	Moisture (%)	Lipid (% db)	Protein (% db)	Carbohydrate (% db)
Whole sorghum	Native (control)	11.17 ± 0.11^{a}	3.88 ± 0.18^{a}	11.90 ± 0.46^{a}	84.49 ± 0.99^{a}
	Spontaneous	9.42 ± 0.63^{b}	3.46 ± 0.27^{b}	11.85 ± 0.69^{a}	85.06 ± 2.22^{a}
	Ragi	9.39 ± 0.79^{b}	3.70 ± 0.57^{ab}	10.87 ± 0.46^{a}	84.79 ± 0.58^{a}
Waxy coix	Native (control)	6.06 ± 0.14^{c}	2.57 ± 0.45^{c}	5.97 ± 0.44^{b}	87.65 ± 0.29^{b}
	Spontaneous	9.67 ± 0.46^{d}	1.48 ± 0.76^{d}	6.57 ± 0.83^{b}	87.74 ± 0.69^{b}
	Ragi	9.38 ± 0.05^{d}	2.06 ± 0.18^{cd}	6.88 ± 0.86^{b}	87.20 ± 1.21^{b}
White maize	Native (control)	6.27 ± 0.06^{e}	2.21 ± 0.06^{c}	6.59 ± 0.13^{b}	89.83 ± 0.39^{b}
	Spontaneous	8.95 ± 0.43^{f}	1.69 ± 0.76^{d}	6.60 ± 1.03^{b}	89.51 ± 0.22^{b}
	Ragi	8.26 ± 0.87^{f}	1.87 ± 0.09^{cd}	6.59 ± 0.40^{b}	88.52 ± 0.12^{b}
p-value	Cereal type	0.000	0.000	0.000	0.000
	Fermentation method	0.000	0.017	0.736	0.276
	Cereal × Fermentation	0.000	0.738	0.169	0.575

Means followed by different lowercase superscripts within columns are significantly different ($p \leq 0.05$).

A major decrease in lipid was detected in spontaneous fermented flours. This could be associated with leaching or high microbial activities during fermentation (Kumoro *et al.,* 2020). It has been highlighted that among the microbial abundance in spontaneous fermentation, *Lactobacillus* is the predominant species (Rahmawati *et al.,* 2013; Coda *et al.,* 2014; Park *et al.,* 2020). During spontaneous fermentation, *Lactobacillus* spp. would produce some extracellular enzymes such as saccharolytic, proteolytic, and lipolytic enzymes, which have a significant role in some nutrient bioavailability alteration (Gunawan *et al.,* 2015; Nkhata *et al.,* 2018; Park *et al.,* 2020). Our earlier work indicated that *Lactobacillus* spp. produced higher lipolytic enzymes, thus leading to higher lipid degradation during fermentation (Gong *et al.,* 2020).

On the other hand, the fermentation did not significantly affect the cereal flours' protein values ($p \geq 0.05$). Thus, the protein content of native cereal flour was not significantly different from spontaneous and *ragi* fermented flours' protein contents. Similar result regarding persistent protein after fermentation was also reported in *Amorphophallus* sp. and teff flour (Koni *et al.,* 2017; Marti *et al.,* 2017). Although another study reported an increase (Istianah *et al.,* 2018), others reported a decrease (Pranoto *et al.,* 2013; Syahputri and Wardani, 2015; Park *et al.,* 2020) in proteins and amino acids during fermentation. These different results might be attributed to different experimental designs, preparation methods, fermentation times, temperatures, initial starter cultures, and nutritional variation of samples.

It is noteworthy that the present work used cereal grains as the substrate (*i.e.,* the grains were directly fermented before being ground into flour), while other experiments were performed using flours as the substrate (*i.e.,* the materials were milled into flour before fermented). It could be assumed that this different particle size influenced the substrate C/N ratio and microbial activity during fermentation. Decreasing cereal particle size would increase the contact area between substrate and microorganisms during fermentation, thus activating some extracellular enzymes that contribute to protein changes (Garrido-Galand *et al.*, 2021).

The present work also showed no alteration in the carbohydrate content of cereal flours after 72 h fermentation. This finding agrees with an observation in rice grains that showed no significant change in the total starch content during fermentation (Park *et al.*, 2020), thus indicating that the degree of fermentation was insufficient to induce hydrolysis in the amorphous region of starch. However, several studies observed that the effect of fermentation on the cereal carbohydrate had broad variation. Some studies identified carbohydrate degradation (Adiandri and Hidayah, 2019; Kumoro *et al.*, 2020), while other claimed carbohydrate enhancement (Adebiyi *et al.*, 2017) following fermentation. Similar to protein, the unchanged carbohydrate of cereal flours observed in the present work might also be attributed to the grain particle size. The large particle size of cereal grains might become a restricting factor that caused the hydrolysis of carbohydrate molecules to occur less, thus resulting in carbohydrate retention following fermentation. It was reported that several pre-treatments on cereal grains, such as milling and germination, would support the effectiveness of endogenous enzymes metabolism and microbial activity during fermentation (Majzoobi *et al.*, 2016; Nkhata *et al.*, 2018; Garrido-Galand *et al.*, 2021).

Sorghum flour had the highest protein and lipid contents but the lowest carbohydrate among the cereal flours. This was reasonable considering that protein is the second largest component in sorghum seeds (Kulamarva *et al.*, 2009). Furthermore, sorghum is also known as a lipid source, with its content being higher than in wheat and rice (Felicia, 2006; Kulamarva *et al.*, 2009). Earlier studies also stated that sorghum had lower carbohydrates than other cereal commodities (Felicia, 2006; Suarni, 2012; Suarni and Firmansyah, 2013).

Functional properties

Table 4 summarises the impact of different fermentation methods on the functional properties of cereal flours. Whole sorghum flour had the highest amylose, while white maize flour had the lowest. The proportion of amylose is affected by the starch (Marques *et al.*, 2006). Maize and coix used in the present work were waxy cereals, so it is plausible that the flour produced had low amylose due to its high amylopectin.

Ragi fermentation resulted in the lowest amylose content of cereal flours. This is consistent with the previous report which stated that the amylose content of job tears or coix flours decreased significantly during fermentation (Dewana, 2019). Since *Saccharomyces* is the main species in *ragi* fermentation (Azmi *et al.*, 2010; Law *et al.*, 2011), probably the amylolytic yeast activities could have led to more amylose released from starch granules, and solubilised in water during fermentation, thus resulting in a visible decrease in amylose content (van der Maarel *et al.*, 2002; Kumoro *et al.*, 2020). It was reported that yeast as a strain-dependant feature, in particular *S. cerevisiae*, *Candida krusei*, and *C. famata*, have a high amylolytic activity during fermentation (Rahmawati *et al.*, 2013; Chaves-López *et al.*, 2020).

The folate content in whole sorghum flour was the lowest among the cereal flours. However, waxy coix and white maize flour had no significant difference in the folate content. Folate, also known as vitamin B_9, is essential for human metabolism, and its deficiency may lead to several health problems such as anaemia, megaloblastic, neural tube defects, and colorectal cancer (Bationo *et al.*, 2020). The fermentation methods had no impact on the folate content of cereal flours. This finding contradicted with previous observations that claimed fermentation could increase the synthesis of folate (Poutanen *et al.*, 2009; Bationo *et al.*, 2020). However, it had been explained that sometimes fermentation of any kind of duration had no significant influence on the folate content (Saubade *et al.*, 2018). Therefore, the steady folate content after fermentation could be assumed because there was no folate produced throughout fermentation, or there was an equal between folate auxotrophy and prototrophy since microorganisms could produce and consume folate (Saubade *et al.*, 2018).

Whole sorghum flour had higher insoluble and total dietary fibres than white maize flour ($p \leq 0.05$). However, the three kinds of cereal flours had no difference in their soluble fibre ($p > 0.05$). There was also no difference in the native and fermented flours ($p > 0.05$). Some researchers also reported that flour's dietary fibre content occasionally remains constant after fermentation (Marti *et al.*, 2017).

Table 4. Effects of different fermentation methods on the functional properties of the cereal flours.

Cereal type	Fermentation method	Amylose (%)	Folate (µg/g)	Soluble fibre (%)	Insoluble fibre (%)	Total fibre (%)
Whole sorghum	Native (control)	28.68 ± 0.39^{a}	149.2 ± 2.95^{a}	0.94 ± 0.35^{a}	0.56 ± 0.04^{a}	1.50 ± 0.08^{a}
	Spontaneous	27.02 ± 1.97^{ab}	154.0 ± 11.8^{a}	0.89 ± 0.10^{a}	0.63 ± 0.14^{a}	1.52 ± 0.24^{a}
	Ragi	25.58 ± 2.55^{b}	162.4 ± 9.87^{a}	0.80 ± 0.09^{a}	0.56 ± 0.19^{a}	1.36 ± 0.28^{a}
Waxy coix	Native (control)	24.88 ± 0.66^{c}	194.0 ± 2.40^{b}	0.89 ± 0.03^{a}	0.47 ± 0.03^{ab}	1.36 ± 0.04^{ab}
	Spontaneous	22.69 ± 1.02^{cd}	175.8 ± 6.68^{b}	0.81 ± 0.17^{a}	0.51 ± 0.19^{ab}	1.32 ± 0.36^{ab}
	Ragi	19.81 ± 1.60^{d}	185.2 ± 8.70^{b}	0.81 ± 0.16^{a}	0.47 ± 0.17^{ab}	1.28 ± 0.32^{ab}
White maize	Native (control)	15.80 ± 0.20^{e}	173.3 ± 2.71^{b}	0.80 ± 0.04^{a}	0.41 ± 0.14^{b}	1.16 ± 0.03^{b}
	Spontaneous	13.50 ± 2.83^{ef}	186.5 ± 13.1^{b}	0.71 ± 0.04^{a}	0.35 ± 0.06^{b}	1.05 ± 0.09^{b}
	Ragi	12.93 ± 4.50^{f}	178.1 ± 10.8^{b}	0.80 ± 0.15^{a}	0.40 ± 0.12^{b}	1.20 ± 0.26^{b}
p-value	Cereal type	0.000	0.000	0.115	0.019	0.024
	Fermentation method	0.008	0.366	0.271	0.954	0.857
	Cereal × Fermentation	0.870	0.024	0.673	0.898	0.835

Means followed by different lowercase superscripts within columns are significantly different ($p \leq 0.05$).

Conclusion

There was no difference in the physical characteristics of cereal flours produced from spontaneous and *ragi* fermentations. Spontaneous and *ragi* fermented cereal flours had brighter colours than native flour but lower water-binding capacity and viscosity. However, there was almost no alteration in cereal flours' chemical and functional properties following fermentation, except for lipid and amylose. Spontaneous fermentation significantly decreased the lipid content of cereal flour, while *ragi* fermentation significantly decreased the amylose content. Generally, fermented sorghum flours had better nutritional properties than white-maize and coix flour, especially lipid, protein, and dietary fibre.

Acknowledgment

The present work was financially supported by the Indonesian Agency for Agricultural Research and Development through the Assessment Institute of Agricultural Technology Central Java. The authors are also thankful to the post-harvest team at Central Java Assessment Institute for Agricultural Technology for their assistance.

References

Aboubakar, Njintang, Y. N., Scher, J. and Mbofung, C. M. F. 2008. Physicochemical, thermal properties, and microstructure of six varieties of taro (*Colocasia esculenta* L. Schott) flours and starches. Journal of Food Engineering 86: 294-305.

Adebiyi, J. A., Obadina, A. O., Adebo, O. A. and Kayitesi, E. 2017. Comparison of nutritional quality and sensory acceptability of biscuits obtained from native, fermented, and malted pearl millet (*Pennisetum glaucum*) flour. Food Chemistry 232: 210-217.

Adiandri, R. S. and Hidayah, N. 2019. Effect of fermentation using *Lactobacillus casei* on the physicochemical and functional properties of sorghum flour. IOP Conference Series - Earth and Environmental Science 309: article ID 012025.

Aini, N., Wijonarko, G. and Sustriawan, B. 2016. Physical, chemical, and functional properties of corn flour processed by fermentation. Agritech 36(2): 160-169.

Aktaş, K. and Akın, N. 2020. Influence of rice bran and corn bran addition on the selected properties of tarhana, a fermented cereal-based food product. LWT - Food Science and Technology 129: article ID 109574.

American Association for Cereal Chemists (AACC). 2000. AACC approved methods of analysis. 11th ed. United States: AACC.

Asp, N. G., Johansson, C. G., Hallmer, H. and Siljestróm, M. 1983. Rapid enzymatic assay of insoluble and soluble dietary fiber. Journal of Agricultural and Food Chemistry 31(3): 476-482.

Azmi, A. S., Ngoh, G. C., Mel, M. and Hasan, M. 2010. *Ragi tapai* and *Saccharomyces cerevisiae* as potential coculture in viscous fermentation medium for ethanol production. African Journal of Biotechnology 9(42): 7122-7127.

Bationo, F., Humblot, C., Songré-Ouattara, L. T., Hama-Ba, F., Le Merrer, M., Chapron, M., … and Hemery, Y. M. 2020. Total folate in West African cereal-based fermented foods: Bioaccessibility and influence of processing. Journal of Food Composition and Analysis 85: 103309.

Capriles, V. D., dos Santos, F. G. and Arêas, J. A. G. 2016. Gluten-free breadmaking: Improving nutritional and bioactive compounds. Journal of Cereal Science 67: 83-91.

Chaves-López, C., Rossi, C., Maggio, F., Paparella, A. and Serio, A. 2020. Changes occurring in spontaneous maize fermentation: An overview. Fermentation 6(36): 1-25.

Coda, R., Di Cagno, R., Gobbetti, M. and Rizzello, C. G. 2014. Sourdough lactic acid bacteria: Exploration of non-wheat cereal-based fermentation. Food Microbiology 37: 51-58.

Dewana, M. A. 2019. The effects of tape yeast fermentation on the physical quality of job's tears flakes. Indonesia: Soegijapranata Catholic University, PhD thesis.

Elkhalifa, A. E. O., Schiffler, B. and Bernhardt, R. 2005. Effect of fermentation on the functional properties of sorghum flour. Food Chemistry 92: 1-5.

Felicia, A. 2006. Development of ready-to-eat breakfast cereal products based on sorghum. Indonesia: IPB University, PhD thesis.

Garrido-Galand, S., Asensio-Grau, A., Calvo-Lerma, J., Heredia, A. and Andrés, A. 2021. The potential of fermentation on nutritional and technological improvement of cereal and legume flours: A review. Food Research International 145: article ID 110398.

Gong, S., Xie, F., Lan, X., Zhang, W., Gu, X. and Wang, Z. 2020. Effects of fermentation on compositions, color, and functional properties of gelatinized potato flours. Journal of Food Science 85(1): 57-64.

Gunawan, S., Widjaja, T., Zullaikah, S., Ernawati, L., Istianah, N., Aparamarta, H. W. and Prasetyoko, D. 2015. Effect of fermenting cassava with *Lactobacillus plantarum*, *Saccharomyces cereviseae*, and *Rhizopus oryzae* on the chemical composition of their flour. International Food Research Journal 22(3): 1280-1287.

Istianah, N., Ernawati, L., Anal, A. K. and Gunawan, S. 2018. Application of modified sorghum flour for improving bread properties and nutritional values. International Food Research Journal 25(1): 166-173.

Kariluoto, S. and Piironen, V. 2009. Total folate. In Shewry, P. R. and Ward, J. L. (eds). Health Grain Methods - Analysis of Bioactive Components in Small Grain Cereals, p. 59-68. United States: Elsevier.

Koni, T. N. I., Zuprizal, Rusman and Hanim, C. 2017. The effect of fermentation on the nutritional content of *Amorphophallus* sp. as poultry feed. In the 7th International Seminar on Tropical Animal Production, p. 313-318. Yogyakarta, Indonesia.

Kulamarva, A. G., Sosle, V. R. and Raghavan, G. S. V. 2009. Nutritional and rheological properties of sorghum. International Journal of Food Properties 12: 55-69.

Kumoro, A. C., Widiyanti, M., Ratnawati, R. and Retnowati, D. S. 2020. Nutritional and functional properties changes during facultative submerged fermentation of gadung (*Dioscorea hispida* Dennst) tuber flour using *Lactobacillus plantarum*. Heliyon 6(3): article ID e03631.

Law, S. V., Abu Bakar, F., Mat Hashim, D. and Abdul Hamid, A. 2011. Popular fermented foods and beverages in Southeast Asia. International Food Research Journal 18: 475-484.

Lestari, D., Kresnowati, M. T. A. P., Rahmani, A., Aliwarga, L. and Bindar, Y. 2019. Effect of hydrocolloid on characteristics of gluten free bread from rice flour and fermented cassava flour (FERCAF). Reaktor 19(3): 89-95.

Lu, Z. H., Li, L. T., Min, W. H., Wang, F. and Tatsumi, E. 2005. The effects of natural fermentation on the physical properties of rice flour and the rheological characteristics of rice noodles. International Journal of Food Science and Technology 40(9): 985-992.

Majzoobi, M., Pesaran, Y., Mesbahi, G. and Farahnaky, A. 2016. Evaluation of the effects of hydrothermal treatment on rice flour and its related starch. International Journal of Food Properties 19: 2135-2145.

Marengo, M., Bonomi, F., Marti, A., Pagani, M. A., Elkhalifa, A. E. O. and Iametti, S. 2015. Molecular features of fermented and sprouted sorghum flours relate to their suitability as components of enriched gluten-free pasta. LWT - Food Science and Technology 63: 511-518.

Mariotti, M., Alamprese, C., Pagani, M. A. and Lucisano, M. 2006. Effect of puffing on ultrastructure and physical characteristics of cereal grains and flours. Journal of Cereal Science 43: 47-56.

Marques, P. T., Perego, C., Le Meins, J. F., Borsali, R. and Soldi, V. 2006. Study of gelatinization process and viscoelastic properties of cassava starch: Effect of sodium hydroxide and ethylene glycol diacrylate as cross-linking agent. Carbohydrate Polymers 66: 396-407.

Marti, A., Marengo, M., Bonomi, F., Casiraghi, M. C., Franzetti, L., Pagani, M. A. and Iametti, S. 2017. Molecular features of fermented teff flour relate to its suitability for the production of enriched gluten-free bread. LWT - Food Science and Technology 78: 296-302.

Moroni, A. V., Iametti, S., Bonomi, F., Arendt, E. K. and Dal Bello, F. 2010. Solubility of proteins from non-gluten cereals: A comparative study on combinations of solubilising agents. Food Chemistry 121: 1225-1230.

Nkhata, S. G., Ayua, E., Kamau, E. H. and Shingiro, J. B. 2018. Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. Food Science and Nutrition 6: 2446-2458.

Ntso, A. S. A., Njintang, Y. N. and Mbofung, C. M. F. 2017. Physicochemical and pasting properties of maize flour as a function of the interactive effect of natural-fermentation and roasting. Journal of Food Measurement and Characterization 11(2): 451-459.

Nursiwi, A., Bedri Sekar, N., Supriyanto and Rahayu, E. S. 2018. Development of the traditional *tape ketan* into probiotic drink with the supplementation of lactic acid bacteria. Indonesian Food and Nutrition Progress 15(1): 11-20.

Nwokocha, L. M. and Williams, P. A. 2011. Comparative study of physicochemical properties of breadfruit (*Artocarpus altilis*) and white yam starches. Carbohydrate Polymers 85: 294-302.

Park, J., Sung, J. M., Choi, Y.-S. and Park, J.-D. 2020. Effect of natural fermentation on milled rice grains: Physicochemical and functional properties of rice flour. Food Hydrocolloids 108: article ID 106005.

Poutanen, K., Flander, L. and Katina, K. 2009. Sourdough and cereal fermentation in a nutritional perspective. Food Microbiology 26: 693-699.

Pranoto, Y., Anggrahini, S. and Efendi, Z. 2013. Effect of natural and *Lactobacillus plantarum* fermentation on *in-vitro* protein and starch digestibilities of sorghum flour. Food Bioscience 2: 46-52.

Rahmawati, Dewanti-Hariyadi, R., Hariyadi, P., Fardiaz, D. and Richana, N. 2013. Isolation and identification of microorganisms during spontaneous fermentation of maize. Journal of Food Technology and Industry 24(1): 33-39.

Rocchetti, G., Lucini, L., Rodriguez, J. M. L., Barba, F. J. and Giuberti, G. 2019. Gluten-free flours from cereals, pseudocereals and legumes: Phenolic fingerprints and *in vitro* antioxidant properties. Food Chemistry 271: 157-164.

Sandhu, K. S., Kaur, M., Singh, N. and Lim, S. 2008. A comparison of native and oxidized normal and waxy corn starches: Physicochemical, thermal, morphological and pasting properties. LWT - Food Science and Technology 41: 1000-1010.

Saubade, F., Hemery, Y. M., Rochette, I., Guyot, J. P. and Humblot, C. 2018. Influence of fermentation and other processing steps on the folate content of a traditional African cereal-based fermented food. International Journal of Food Microbiology 266: 79-86.

Suarni and Firmansyah, I. U. 2013. Sorghum structure, nutritional composition and processing technology. In Sumarno, Damardjati, D. S., Syam, M. and Hermanto (eds). Sorghum - Technological Innovation and Development, p. 260-279. Indonesia: IAARD Press.

Suarni. 2012. Sorghum as a functional food. Iptek Tanaman Pangan 7(1): 58-66.

Syahputri, D. A. and Wardani, A. K. 2015. Effects of jali (*Coix lacryma jobi*-L) fermentation in flour produstion on physical and chemical characteristics of cookies and white bread. Jurnal Pangan dan Agroindustri 3(3): 984-995.

Väkeväinen, K., Ludena-Urquizo, F., Korkala, E., Lapveteläinen, A., Peräniemi, S., von Wright, A. and Plumed-Ferrer, C. 2020. Potential of quinoa in the development of fermented spoonable vegan products. LWT - Food Science and Technology 120: article ID 108912.

van der Maarel, M. J. E. C., van der Veen, B., Uitdehaag, J. C. M., Leemhuis, H. and Dijkhuizen, L. 2002. Properties and applications of starch-converting enzymes of the α-amylase family. Journal of Biotechnology 94(2): 137-155.

Xu, M., He, D., Teng, H., Chen, L., Song, H. and Huang, Q. 2018. Physiological and proteomic analyses of coix seed aging during storage. Food Chemistry 260: 82-89.

Zhao, T., Li, X., Zhu, R., Ma, Z., Liu, L., Wang, X. and Hu, X. 2019. Effect of natural fermentation on the structure and physicochemical properties of wheat starch. Carbohydrate Polymers 218: 163-169.