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Physicochemical properties of corn flour modified by mixed-culture (*Aspergillus* sp. and *Lactobacillus fabifermentans*) fermentation

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Abstract

Corn flour has undergone numerous modifications, however, the use of fermentation with Indigenous mixed cultures (molds and bacteria) followed by pregelatinization has not been extensively explored. The aim of the study was to assess the impact of fermentation with indigenous mixed cultures, specifically *Aspergillus* sp. (AS) and *Lactobacillus fabifermentans* (LF), on the physicochemical properties of modified corn flour, as well as its application in product quality. Corn flour was fermented using mixed cultures of AS and LF in a Complete Random Design (CRD) at five different ratios (AS: LF) of 1:0, 1:1, 1:2, 1:3, and 0:1. Each culture was incubated for 120 hours for AS and 48 hours for LF, then diluted by mixing 1 mL of the culture with 10 mL of sterile water. This diluted solution (according ratio) was aseptically added to a sterile corn flour dispersion at a ratio of 1:2 (w/v) and fermented under microaerophilic conditions for 48 hours. The fermented dispersions were dried and subsequently steamed (80°C) for 15 minutes at a 30% (w/v) ratio to prepare samples for analysis of amylose content, starch content, pasting, and rheological properties. The optimal AS: LF ratio determined through statistical analysis was 1:3, resulting in a final pH of 3.60 ± 0.10. The physicochemical properties of the corresponding steamed samples were as follows: amylose content (%), 17.45 ± 0.62; starch content (%), 68.94 ± 0.69; apparent consistency index (cP), 25,286 ± 512.9; and apparent power-law index, 0.32 ± 0.005, indicating pseudoplastic rheological behavior. The modified corn flour (AS: LF at 1:3) was then used in a 50% formulation for making bread and noodles. The resulting products showed potential for larger-scale development.

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Modified Corn Flour, Fermented Pregelatinized Flour, Mixed Cultures, Physicochemical Properties.

1. Introduction

Starch is a carbohydrate composed of glucose units linked by glycosidic bonds. Corn stores glucose in the form of starch, which is a polysaccharide. The starch content in corn varies depending on the type. For instance, Corn Bisi-2 has a starch content of approximately 60.87%, while POP contains about 56.86% (1). The Bisi-18 hybrid corn variety is widely grown in Indonesia. This corn variety provides significant benefits to farmers due to its large and uniform cob size (2). The hybrid corn Bisi-18 is reported to have about carbohydrates 77.68%, protein 6.88%, fat 3.45%, water 10.78%, ash 1.21%, and hardness level of 403.14 (3), indicating its potential as a food product.

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The starch content and variety of corn significantly influence its functional properties. Key differences in pasting profiles and thermal properties can be observed among different starches (4). The physicochemical, thermal, and rheological characteristics of corn starch are largely determined by its type. Hybrid varieties yield the highest amount of starch, which also contains the greatest levels of fat, moisture, and protein while exhibiting the lowest onset temperature of gelatinization (5).

Although valuable in the food industry, starch in its native form has several limitations, such as a tendency toward retrogradation, high viscosity even at low concentrations, handling issues, poor freeze-thaw stability, low process tolerance, and gel opacity that hinder its use in food processing (6). Therefore, modified starches are utilized in numerous processed foods due to their enhanced functional properties compared to native starches (7) and fermentation is a notable method. Fermentation reduces the enthalpy, which makes the starch structure more rigid and diminishes its crystalline characteristics. During fermentation, bacterial activity breaks the carbon bonds in starch into smaller fragments. As a result, fermentation can lower the peak viscosity, breakdown value, final viscosity, and trough viscosity of the flour (8). In addition, corn contains anti-nutritional compounds like tannins, phytic acid, and oxalate (9,10). Fermentation reduces these anti-nutritional compounds (11) and increases nutritional content, such as protein, amino acids (lysine), and polyphenol in the resulting corn flour (12).

Aspergillus sp. (13), *Enterobacter cloacae subs. cloacae* (14) and *Lactobacillus fabifermentans* (15) have been successfully isolated from spontaneous fermentation corn flour, and *Aspergillus* sp. with *L. fabifermentans* are used as starters in corn flour modifications (16,17). *Aspergillus* sp. are notable as they produce amylase (18,19) and gluco-amylase (20) to degrade starch. Corn flour was fermented for 24 hours using *Aspergillus* sp. at a 1% (w/v) level to obtain an acceptably treated corn flour with amylose and starch contents of approximately 26% and 52%, respectively. Given the strong influence of amylose content on starch properties, a reduction in amylose content could yield a different product. Fermented corn flour with *Lactobacillus fabifermentans* at a 1% level for 24 hours and obtained a modified flour with a higher amylose content (29%) and lower starch content (49%) than with the *Aspergillus* sp. (21). With these differences in products and actions of these microbial enzymes, fermentation with their mixed cultures is worthwhile to be investigated to understand the mutual or antagonistic actions of the two sources of enzymes.

Fermentation using the single culture *L. casei* has also been shown to modify sweet corn flour. The fermentation process with this bacterium results in a higher quality sweet corn flour compared to flour that has not undergone fermentation. Notably, the fermented flour has reduced moisture content, lower starch levels, decreased crude fiber, and lower total sugar content (22). The fermentation method was effective in improving the quality of corn flour. Additionally, the physicochemical quality of corn flour can be further enhanced when combined with the starch pregelatinization process. This approach can significantly improve the functional properties of flour, in terms of both its physical attributes and functional content.

The modification of taro flour through fermentation using a mixed culture of lactic acid bacteria, specifically *L. plantarum* and *Leuconostoc mesenteroides*, followed by pregelatinization, results in a modified taro flour with high resistant starch, low digestibility starch, and potential as a prebiotic candidate (23). However, the modification of corn flour using the fermentation method followed by pregelatinization, particularly with mixed cultures, has not been extensively researched, most studies have utilized single cultures for this purpose. One study found that fermenting corn flour using *L. plantarum* followed by heat treatment resulted in modified corn flour where starch granules lost their spherical and intact structure, underwent melting and reorganization, and displayed an increase in particle size. These changes significantly improved the thermal stability and textural properties of the corn flour (24). There have also been studies on modifying corn flour with fermentation processes using single cultures, such as Indigenous *L. fabifermentum* or *Aspergillus* sp., followed by pregelatinization. These modifications resulted in corn flour with good dietary fiber content (25) and low digestibility starch (26). In contrast to these previous studies, the current research aims to modify corn flour using a fermentation process with Indigenous mixed cultures followed by pregelatinization.

This approach is expected to enhance the physicochemical quality of modified corn flour compared with that produced using a single indigenous culture. A mixed culture of *Aspergillus* and *L. fabifermentum* is anticipated to optimally modify corn flour. Furthermore, it is hoped that the modified corn flour will yield high-quality food products, thereby becoming a valuable main ingredient for developing locally based products with excellent functional properties. Therefore, the aim of this study was to modify corn flour by fermentation using mixed cultures of *Aspergillus* sp. and *L. fabifermentans* combined with heat-moisture treatments for pregelatinization and how these modifications affected the physicochemical properties of the products.

2. Materials and Methods

2.1. Materials

The main material used in this study was hybrid corn Bisi 18, obtained from the Mattiro Baji farmer group, Bantaeng Regency, South Sulawesi, Indonesia. The cultures used were *Aspergillus* sp. (AS) and *Lactobacillus fabifermentans* (LF) isolated from spontaneous fermentation of corn flour Bisi 16 and developed in the Microbiology Laboratory of Agricultural Technology Education, Universitas Negeri Makassar. The growth media used were MRSA Merck, MRSB Merck, and PDA. All the chemical reagents were of analytical grade.

2.2. Preparation Stages

2.2.1. Making Corn flour

Corn kernels were subjected to grating and subsequently immersed in water for 24 hours, which facilitated separation of the pericarp and germ prior to draining. Following this process, the kernels were processed using a disk mill (MDM-30; Andaro, Malang, Indonesia) and dried in a controlled environment (dryer room; PT ATMI Kreasi Agro, Jakarta, Indonesia) at a temperature range 50-60°C for 48 hours. Finally, the dried material was sieved through an 80 mesh sieve.

2.2.2. Rejuvenation of *Aspergillus* sp.

A pure culture of *Aspergillus* species (AS) derived from the spontaneous fermentation of Bisi-18 corn flour (13) was used in this study. The culture was aseptically transferred using the scratching method and subsequently incubated for 120 hours at 30°C on potato dextrose agar (PDA).

2.2.3. Rejuvenation of *L. fabifermentans*

A pure culture of *L. fabifermentans* (LF), obtained from the spontaneous fermentation of Bisi-18 corn flour (15), was utilized in this study. The culture was aseptically transferred using the injection method and subsequently incubated for 48 hours at 30°C in a De Man, Rogosa, and Sharpe broth (MRSB).

2.3. Implementation Stages

2.3.1. Making *Aspergillus* sp. and *L. fabifermentans* Starters

Each incubated culture was diluted by combining 1 mL of the culture with 10 mL of sterile water. This diluted solution was then aseptically incorporated into a sterile dispersion of corn flour at a ratio of 1:2 (w/v) and was fermented under microaerophilic conditions for a duration of 48 hours.

2.3.2. Application of Starters

Five ratios of starters, specifically AS: LF ratios of 1: 0, 1: 1, 1: 2, 1: 3, and 0: 1, were examined in conjunction with a corn flour dispersion at a ratio of 1: 2 (w/v). The mixed-culture microaerophilic fermentation process was conducted over a period of 24 hours. Following fermentation, the resultant fermentate was removed and dried for 48 hours at a temperature of 50°C. Subsequently, the dried material was blended using a food disc mill grinder (IC-10B). The pH of the fermenting liquids was measured at the conclusion of the fermentation, adhering to the standards set forth by the AOAC.

2.3.3. Pregelatinization

Water (70% w/v) was added to the fermented corn flour and steamed at 80°C for 15 min. Subsequently, the mixture was dried for 48 hours, blended, and stored until further analysis. The analyses conducted included the determination of amylose content, starch content, and rheological properties (27). The moisture content of the fermented, pregelatinized, and dried samples averaged 6.6 ± 0.91 (%).

A rotational viscometer (Brookfield; Model RVT, Spindle #6, Middleboro, MA 02346-1031, USA) was used for the apparent rheological properties. A known weight (10 g) of each sample was mixed with water (100 mL) before the determination, and the dispersion was rotated at 5, 10, 20, 50 and 100 rpm at 70°C. Although rotational speeds are not exact shear rates, but functions, relationships between viscosity and rotational speeds can be cautiously used to understand apparent rheological behaviours of food systems (19,27). In the present study, results are presented as viscosity-rotational speed sets, and the data were modelled using the power-law equation:

$$\mu = K\,\gamma^{(n-1)} \tag{1}$$

where μ = apparent viscosity, K = apparent consistency index, γ = rotational speed as a measure of shear rate and n = apparent power law index.

2.4. Application Corn Flours Modified in Food Product

2.4.1. Bread Making Method

Flour was measured using a 60:40 ratio, comprising 150 g of modified corn flour and 100 g of wheat flour. Other ingredients included 80 g of sugar for sweet bread (or 40 g for plain bread), 4 g of yeast, 50 g of eggs, 25 g of milk powder, 25 g of margarine, 260 mL of water, and 3 g of salt. To prepare the modified cornstarch gel, the modified cornstarch was dissolved in water. The flour suspension was then heated while stirring until it thickened at 72°C (but did not boil). Once thickened, the flour gel was placed in a container and covered with plastic wrap. The remaining ingredients were combined in the container and mixed using a mixer. The bread dough was mixed until smooth and transferred to a container greased with margarine. It was covered and allowed to rest for 10 minutes. Next, the dough was divided into several portions, each weighing 30 g. The pieces were rounded and allowed to rest for 10 minutes. The dough was then rolled out with a rolling pin to release gas, shaped accordingly, and left to rise (proof) for 60 minutes. Finally, the molded bread was baked in an oven at 180°C for 15 minutes.

2.4.2. Noodle Making Method

The ingredients were measured using a 50% ratio of modified corn flour to 50% wheat flour. For every 100 g of dough, the mixture included 1 g salt, 1 egg, 1 g carboxymethyl cellulose (CMC), and 80 mL water. The weighed ingredients were combined in a designated mixing pan and stirred until they were well-incorporated. The mixture was then heated to 50°C for 6 minutes to facilitate gelatinization, which formed the dough. After heating, the dough was allowed to rest and cool for 30–45 minutes. Once cooled, the dough was divided into four equal parts. The roll press process, which is used for sheet formation, was performed with a level 7 hole noodle-making machine, which is the largest setting. The dough was successively flattened to levels 5 and 3. After reaching Level 3, the flattened dough was cut using noodle molds. Finally, the resulting noodles were dried in a cabinet dryer at 70°C for 2 hours.

2.5. Analysis Method

The chemical analysis method used follows the AOAC procedure (28), namely starch, amylose, pH, proximate (moisture content, ash, fat, protein, and carbohydrate content), fiber, and reducing sugar. The total plate count analysis followed the SNI 01-2332.3-2006 method (29). Sensory analysis of bread and noodle products was carried out by 25 panelists. The analysis includes sensory attributes of colour, aroma, texture, and taste of bread and noodles made from modified corn flour. The sensory attributes were analyzed using a scale of 1-5.

2.6. Statistical Analysis

Samples were analyzed in triplicate and analysis of variance (ANOVA) was conducted using Duncan's t-test at a confidence level of 95%.

3. Results and Discussion

3.1. The pH Value

Potential of Hidrogen (pH) is an important parameter during fermentation, as microbial growth and microbial enzyme activities are strongly dependent on pH (30). Figure 1 shows the pH of the fermented corn flour at the end of the fermentation, with the presence of the *L. fabifermentans* significantly reducing the pH leading to AS: LF 1: 3 (pH = 3.6 ± 0.10) and 1:2 (pH = 3.80 ± 0.10) producing the most sour samples in the treatments.

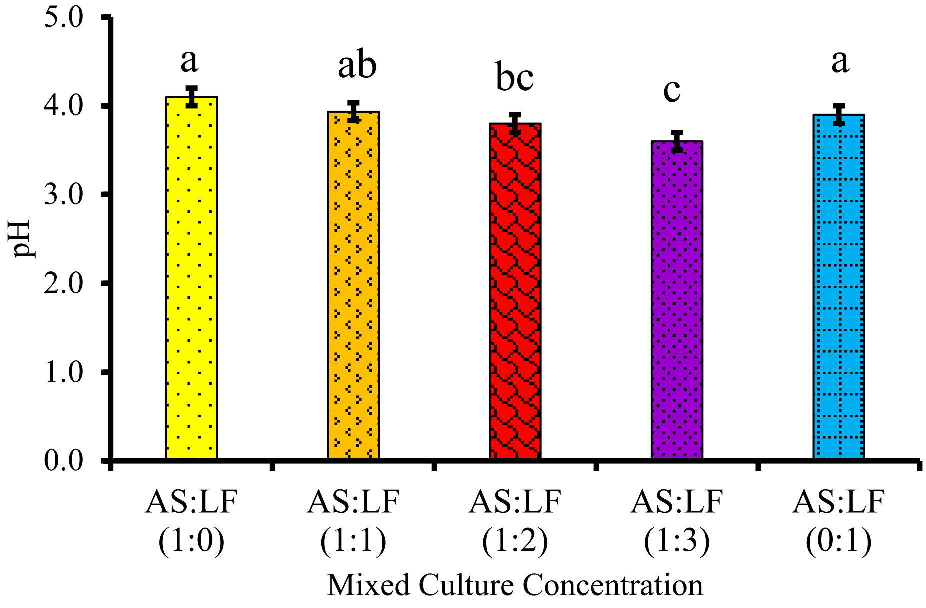


Figure 1: The pH of corn flour after fermentation with the cultures. Note: different letters (a, ab, bc, c) are significantly different ($p<0.05$). AS = *Aspergillus sp*. LP = *Lactobacillus fabifermentans*

This observation is expected because lactic acids are produced by *Lactobacillus* genus, lowering the pH, extracellular amylases are produced and degradation of the corn starch heterofermentatively occurred, with ethanol and carbon dioxide being the side products (31,32). The lactic acid produced under more acidic conditions also prevented the unwanted growth of other microbes. Decreases in pH are also thought to be influenced by indigenous bacteria, where they are thought to remain alive in corn flour, especially from the *Lactobacillus* genus. Lactic acid bacteria are the dominant indigenous bacteria during the spontaneous fermentation of corn flours. The addition of AS: LF mixed cultures produces amylases that degrade corn starch to dextrin or maltose, triggering the growth of indigenous lactic acid bacteria.

The pH value in this research was lower than pH value of 4.92, when corn flour was fermented by 1% *Aspergillus* sp. (16), of 5.08, when corn flour was fermented by 1% *L. fabifermentans* (17). Perhaps the mixed AS: LF cultures were more effective and the starters acted cooperatively for the reduced pH. Low pH in corn flours is expected to influence physicochemical properties of the flours, like hydrolysis of complex components of the corn flour, increase in amylose or amylopectin linearization through the breakdown of starch α-1,4 and α-1,6 glucosidic bonds and improved dispersion in water (33,34).

3.2. Amylose Content

Amylose is the linear fraction of starch, and although there are high amylose corn varieties, corn starches have medium molecular weight amylose. Figure 2 shows the amylose content of fermented corn flour. It can be observed that the mixed culture had a significant effect on the amylose content. AS: LF 1:0 and 0:1 produced the lowest amylose content, while 1:2 and 1:3 had the highest amylose content, suggesting that the presence of *L. fabifermentans* enhanced amylose, which could be due to the highly acidic conditions.

Glucoamylase, exoenzyme, α-amylase, endoenzyme, basically have the same optimum pH to work, which are respectively 4–5 and 4–6 (35,36). α-amylase produces mixtures of dextrin, maltose and glucose as it severs α-1.4 glycosidic bonds in starches, while glucoamylase severs both α-1.4 and α-1.6 bonds to produce glucose (19).The amylose contents in this research are generally lower than those obtained (16,17) with fermented corn flours using single cultures of *Aspergillus* sp. (26.45%) and *L. fabifermentans* (29.45%). Hence, the mixed cultures in the present study caused more chain severance of amylose and amylopectin.

Aspergillus sp. is a mold that plays a role in the spontaneous fermentation process of corn flour. This mold is typically observed at six hours into the fermentation, displaying white colonies and a greenish-black mycelium when grown on Potato Dextrose Agar (PDA) medium (13). Additionally, *L. fabifermentans* is also present during the spontaneous fermentation of corn flour. This bacterium forms large, round, beige colonies on MRSA and is characterized as Gram +, catalase -, and endospore - (15).

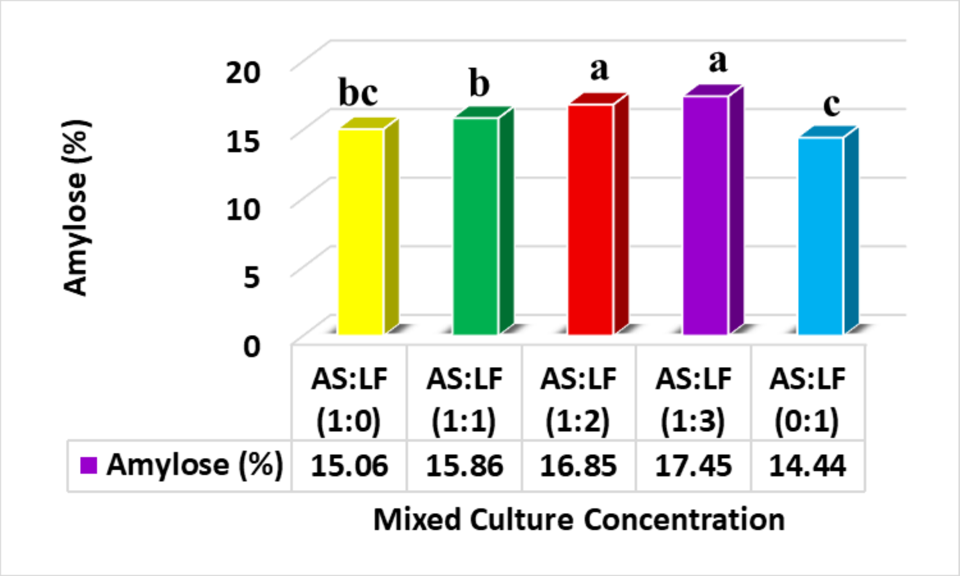


Figure 2. Amylose of the modified corn flours. Note: Different letters (a, b, bc, c) indicate significant differences (p<0.05). AS = *Aspergillus* sp. LP = *Lactobacillus fabifermentans*.

Both types of microbes used in this fermentation are indigenous microbes found in corn, so *Aspergillus sp*. and *L. fabifermentans* can modify amylose because of their ability to produce amylase enzymes. *L. fabifermentans* is a lactic acid bacteria that produces lactic acid as the main metabolite. In the AS:LF 1:3 ratio, the LF composition was the highest compared to other culture ratios, which caused the highest lactic acid production and caused the pH to be the lowest in this treatment. An acidic pH value causes a decrease in the activity of the amylase enzyme produced by both types of microbes that are not in their optimum conditions. In addition, high lactic acid during fermentation in the AS:LF 1:3 treatment, can cause modification of the branch structure through linearization of amylopectin bonds by breaking the α 1.6 D glycosidic bond into a linear structure of α 1.4 D glycosidic bonds, because acid can disrupt the glycosidic bond in the starch fraction. Both of these things cause the amylose content in the AS:LF 1:3 treatment to be the highest compared to other treatments.

3.3. Starch Content

Starch contains hydroxyl groups and simple glycosidic bonds that can be easily modified to enhance its functional properties or to introduce specific features. These modifications can improve cooking properties, gel clarity, texture, adhesion, and film formation, while also increasing freeze-thaw stability or reducing syneresis, retrogradation, and gelling tendencies. Additionally, modifications can enhance the amphiphilicity, hydrophobicity, mechanical strength, and thermal stability of starch(37). Figure 3 shows the starch contents of the samples, with the AS:LF 1:3 ratio having the highest starch content, to show that the *L. fabifermentans* culture enhanced the starch content. It is possible that the starch-degrading enzymes were not optimal under acidic conditions and less starch was degraded, AS:LF 1:3 ratio had the lowest pH (most acidic conditions), whereas the AS:LF 1:0 ratio, with its higher pH (Figure 1), had the lowest starch content.

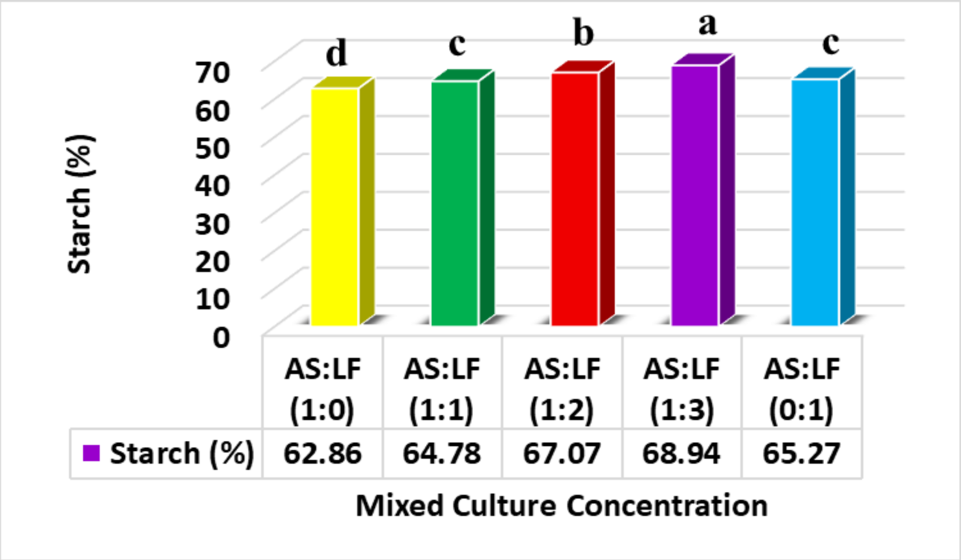


Figure 3. Starch of the modified corn flours. Note: different letters (a, b, c, d) are significantly different ($p<0.05$). AS = *Aspergillus* sp. LP = *Lactobacillus fabifermentans.*

The starch content positively correlates with amylose content, as amylose impedes starch digestion, whereas amylopectin, because of its branched nature, enhances starch digestion. The starch contents in the present study are higher than those from fermented corn flour by single cultures of *Aspergillus* sp. (51.57%) and *L. fabifermentans* (48.73%) (16,17,37).

The results of this study indicate that single cultures, particularly *Aspergillus* sp., cause the greatest decrease in starch content. This is due to *Aspergillus* sp.'s ability to produce enzymes such as amylase and glucoamylase, which break down both amylose and amylopectin, the two components of starch. When *Aspergillus* sp. was mixed with *L. fabifermentans*, both organisms initially grew together by utilizing the substrate to modify corn starch. However, as the starch was broken down, *L. fabifermentans* produced a significant amount of lactic acid, which affected the resulting pH level. Notably, the combination of *Aspergillus* sp. and *L. fabifermentans* at a ratio of 1:3 resulted in the lowest pH value. This low pH negatively impacted the activity of the amylase enzyme, moving it away from its optimal conditions. As a result, the amount of amylose remained the highest, and the overall starch content did not significantly decrease in this treatment.

3.4. Rheological Properties

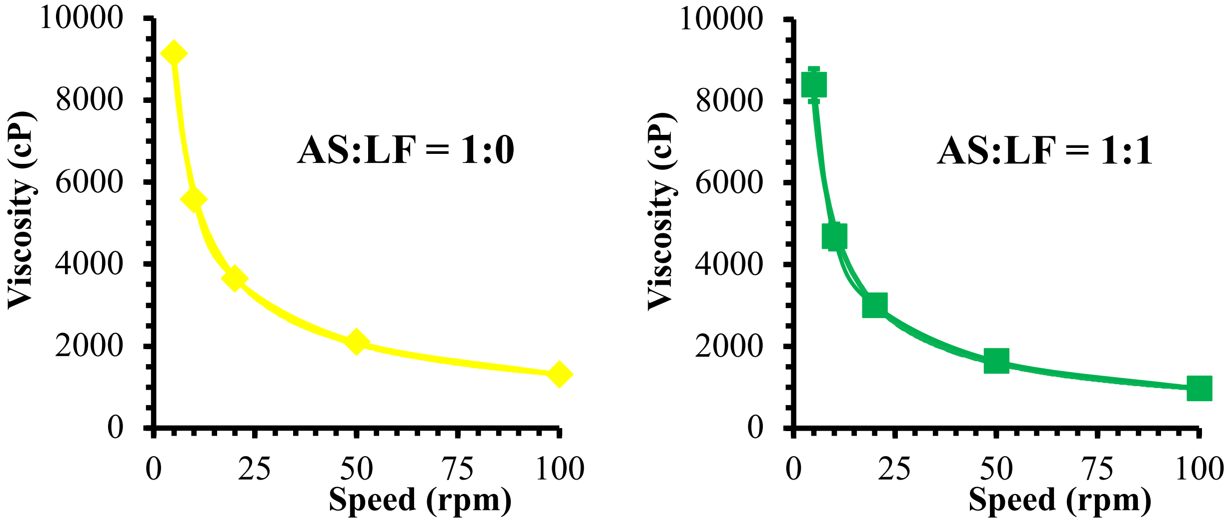
Rheology is the study of deformation and flow of raw materials, processing intermediates and final products (27). Viscosity is the resistance to flow, and it shows how molecules move easily because of the friction between material layers. Amongst others, rheological behaviours simply can manifest in the dependence of viscosities on shear rates, and Figure 4 shows how the viscosities of the samples depended on the rotational speeds. The viscosity decreased as the shear rate (rotational speed) was increased, a case of non-Newtonian pseudoplastic behaviour, and pseudoplastic foods are very suitable for uses as thickeners and food-additives, for example, bread dough from some flour free gluten (38). The power-law equation (Table 1) was suitable ($r^2 > 0.99$) in describing the relationships, and shows the apparent consistency and power-law indices of the samples. The power-law indices were less than 1 to confirm the pseudoplastic behavior of the samples.

Table 1. Rheological properties (apparent) of the modified corn flours.

Rheological Properties (Apparent)	AS: LF (1: 0)	AS: LF (1: 1)	AS: LF (1: 2)	AS: LF (1: 3)	AS: LF (0: 1)
Consistency index (cP)	25,020 b	25,173 b	28,207 a	25,286 b	17,534 c
Power law index	0.36±0.007 a	0.29±0.015 b	0.30±0.022 b	0.32±0.005 b	0.37±0.012 a
R-sq	0.999±0.0003	0.998±0.0004	0.998±0.0010	0.999±0.0005	0.987±0.0151

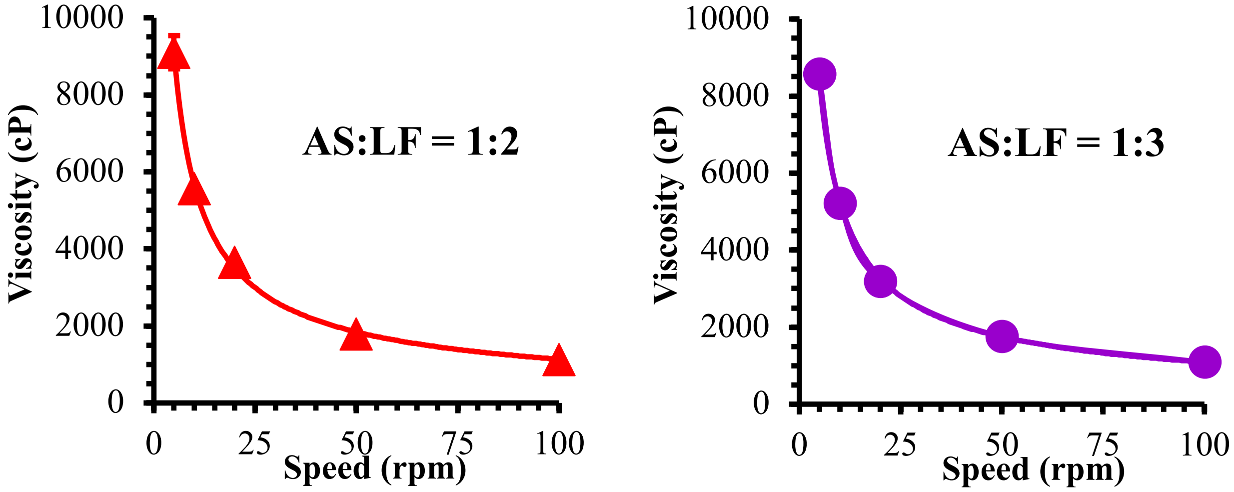
Note: Mean values in a row followed by different letters (a, b, c) are significantly different (p<0.05). AS = Aspergillus sp. LP = Lactobacillus fabifermentans

Mixed culture influenced the consistency and power-law indices. The mixed culture (AS: LF) yielded a generally lower power law index than the single cultures (AS:LF; 1:0 and 0:1) (Table 1). However, the consistency index of the samples was not drastically affected and there was no particular trend, although the single culture of AS:LF (0:1) produced the least viscous sample of 17,534 cP. Corn flour is gluten-free. Similar to other gluten-free flours, such as einkorn wheat, chestnut, rice, and sweet potato, corn flour is classified as a non-Newtonian pseudoplastic (38). The current viscosity measurements do not fully explain the differences in the rheological properties of the five modified corn flour samples. Therefore, a more in-depth study is needed to investigate the pasting, gelatinization, and retrogradation properties of the resulting starch.



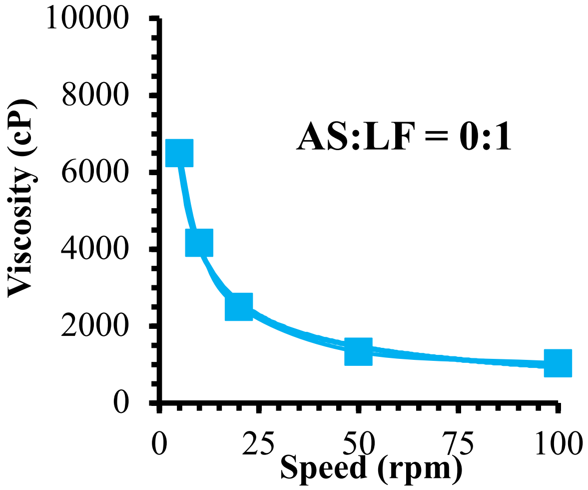
Aspergillus sp. (AS): *L. fabifermentans* (LF) (1: 0)

Aspergillus sp. (AS): *L. fabifermentans* (LF) (1:1)



Aspergillus sp. (AS): *L. fabifermentans* (LF) (1:2)

Aspergillus sp. (AS): *L. fabifermentans* (LF) (1:3)



Aspergillus sp. (AS): *L. fabifermentans* (LF) (0:1)

Figure 4. The viscosity-rotational speed relationships of the sample.

3.5. Quality of Bread and Noodles Made from Modified Corn Flour

Modified corn flour processed through a mixed culture fermentation with a ratio of LF 1:3, followed by pregelatinization, has shown promising results in the production of sweet bread, white bread, and dry noodle products. The incorporation of 50% to 60% of this modified corn flour in bread-making resulted in favorable chemical, microbiological, and sensory qualities for the sweet bread, white bread, and dry noodles produced (Table 2). All resulting products met the Indonesian National Standards (SNI), specifically SNI 01-3480-1995 for sweet bread and SNI 01-2974-1996 for dry noodles. The white bread produced also complied with SNI standards regarding water content, protein, ash, microbial quality, and sensory attributes. However, the sugar and fat content of the white bread exceeded the specified standards. This was due to the relatively low amounts of sugar and margarine used in the white bread formulation.

Table 2. Chemical, microbiological, and hedonic quality of bread and noodles made from modified corn flour.

Parameters	White Bread	Sweet Bread	Dry Noodles
Proximate:			
Moisture content (%)	26.53±0.31	21.78±0.71	9.02±0.45
Ash (%)	1.26±0.03	1.27±0.03	1.63±0.06
Fat (%)	3.91±0.29	4.80±0.25	4.19±0.27
Protein (%)	8.32±0.04	7.89±0.18	12.22±0.40
Carbohydrates (%)	42.70±0.51	43.85±0.48	60.35±1.44
Chemical Contents:			
Fibre (%)	0.36±0.07	0.31±0.02	0.32±0.01
Amylose (%)	13.44±1.95	13.40±1.40	4.94±0.45
Starch (%)	63.03±0.73	47.93±1.62	70.43±0.36
Sugar (%)	3.53±0.08	5.44±0.46	-
Microbiology:			
Total Plate Count (TPC) (Log CFU/g)	6.5±0.30	6.4±0.52	6.4±0.36
Hedonic Attribute:			
Colour	3.49±0.35 (bit yellow)	3.28±0.42 (bit yellow)	2.78±0.13 (brownish yellow)
Aroma	3.16±0.35 (slightly distinctive corn)	3.49±0.27 (slightly distinctive corn)	2.88±0.04 (not typical corn)
Texture	3.39±0.15 (slightly soft)	3.21±0.36 (slightly soft)	3.03±0.16 (slightly crunchy)
Taste	3.53±0.18 (slightly distinctive corn)	3.52±0.21 (slightly distinctive corn)	2.99±0.18 (not typical corn)

The results indicate that this modified corn flour has significant potential for future development. Further studies on its application in formulating and scaling up production are feasible. Notably, this flour can substitute up to 60% of wheat flour in bread making and 50% in the production of dry noodles.

4. Conclusions

Addition of mixed cultures of *Aspergillus* sp. and *L. fabifermentans* influenced the physicochemical properties of the modified corn flour produced. Mixed culture concentrations of *Aspergillus* sp. and *L. fabifermentans* (1:3) treatment gave an acceptable product with desirable properties (high starch and amylose contents) that would influence starch digestibility. Modified corn flour AS: LF (1:3) can be used in the production of bread and noodle products, allowing for an increase of up to 50%.

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Author Contributions

A.S. conceived and designed the experiments; A.S. and R.P.P. performed the experiments; A.S. and R.F. analyzed the data; R.F. and I.S.M.A.T. contributed reagents/materials/analysis tools; A.S. and R.P.P. wrote the paper.

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Institutional Review Board Statement

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Data Availability Statement

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Conflicts of Interest

No conflict of interest.

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