Food Research 7 (1) : 120 - 127 (February 2023)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

The benefits of fermentation in improving the pasting properties of composite sweet potato flour and its application in composite white salted noodles

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Article history:
Received: 9 September 2021
Received in revised form: 24 October 2021
Accepted: 22 February 2022
Available Online: 21 January 2023

Keywords:
Composite white salted noodles,
Fermented sweet potato flour,
Pasting properties

DOI:
https://doi.org/10.26656/fr.2017.7(1).712

Abstract

Fermentation treatments change the pasting properties of sweet potato flour, which may improve its utilization in composite flour. This research was carried out to evaluate the pasting properties of composite fermented sweet potato flour and the quality of composite salted noodles using those composite flour. Sweet potato slices were fermented using five different starters (spontaneous, *Lactobacillus plantarum, Leuconostoc mesenteroides,* a mix of *Lactobacillus plantarum* and *Leuconostoc mesenteroides,* and a mix of *Lactobacillus plantarum, Leuconostoc mesenteroides,* and *Saccharomyces cerevisiae)*, and processed into flour. Native sweet potato flour without fermentation was also prepared as a control. A total of six sweet potato flour (SPF) were then used to substitute 50% of the wheat flour in composite white salted noodles. Then, the pasting properties of the composite flour and the quality of the noodles were evaluated. Results proved that composite fermented SPF had higher pasting properties (peak and final viscosity, break down, and set back value) than those of composite non-fermented SPF. The substitution for fermented SPF in composite white salted noodles decreased cooking loss, cooking time, solid loss, soluble loss, swelling index, adhesiveness, and water absorption, while cohesiveness, elasticity, elongation, and colour brightness increased significantly. Therefore, the incorporation of fermented SPF enhanced the quality of composite white salted noodles.

1. Introduction

Sweet potato (SP) tuber can be processed into flour to be used in composite flour for food-making. However, the level of SP flour utilization as wheat flour substitution that is acceptable for consumers is still low at less than 30% (Shan *et al*., 2013; Yadav *et al*., 2014; Nzamwita *et al*., 2017). The functional and sensory properties of sweet potato flour need improvement.

Previous studies reported that fermentation as a microbiological method to improve the functional and sensory properties of flour was promising. Fermentation can improve the functional properties of the flour through modification of the starch granule surface (Park *et al*., 2020) and disruption of the starch ordered structures (Li *et al*., 2019). The functional properties of rice flour (Park *et al*., 2020; Li *et al*., 2019; Satmalee *et al*., 2017), sweet potato flour (Ajayi *et al*., 2016; Ajayi *et al*., 2019), composite flour with sweet potato flour (Kemi *et al*., 2017; Yuliana *et al*., 2017; Yuliana *et al*., 2018), cassava flour (Gunawan *et al*., 2015), and breadfruit flour (Rahma *et al*., 2017) were increased through fermentation. In addition, the whiteness score of flour increased sharply with increasing fermentation time (Yuliana *et al*., 2018), and a better flavour was observed in fermented sweet potato flour (Ajayi *et al*., 2019), which may preferable for the sensory properties. Hence, fermented flour have great potential as wheat flour substitute.

Using fermented flour to substitute wheat flour in composite flour to develop food products, like noodles, has attracted great interest as fermentation may improve product quality. Fermentation increases granule damage due to the actions of acids and enzymes (Díaz *et al*., 2018). Moreover, the differences in broken starch content alter the pasting and thermal profiles, thus influencing the value of processed food products (Ahmed and Thomas, 2017). The starch paste viscosity in flour could be a predicting indicator that determines

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

the quality of the noodles (Sandhu *et al*., 2010; Li *et al*., 2017; Yi *et al*., 2020).

Numerous studies have developed composite flour with the incorporation of fermented flour to develop food products. However, few studies have observed the application of fermented flour made from sweet potatoes, especially for noodle-making. Liao and Wu (2017) used fermented SP starch, while Shan *et al*. (2013) and Yadav *et al*. (2014) incorporated the native SP flour into the noodles.

Fermentation for flour production primarily uses lactic acid bacteria and yeast as starters. To date, it is still unclear how concurrent lactic acid bacteria and yeast strains affect the physicochemical of sweet potato flour and its white salted noodles. The presence of these strains together in a fermentation system will determine the structure of fermented sweet potato starch and the characteristics of its resulting composite flour and white salted noodles. Thus, the objective of this study was to explore the pasting behaviour and how this property affects the characteristics of composite salted noodles. In this study, two strains of lactic acid bacteria (*Lactobacillus plantarum* and *Leuconostoc mesenteroides*) and *Saccharomyces cerevisiae* were used as starters to produce fermented SPF. Then, the pasting properties of the composite SPF and the quality of the composite white salted noodles were observed.

2. Materials and methods

2.1 Materials

The primary materials in this study were white sweet potato tubers purchased in traditional markets in Bandar Lampung, Indonesia; *Lactobacillus plantarum* FNCC 0123 and *Leuconostoc mesenteroides* FNCC 0023 from the Laboratory of Food, Universitas Gajah Mada; and *Saccharomyces cerevisiae* in the form of commercial instant yeast.

Starters (*Lb. plantarum*, *Lc. mesenteroides*, and *S. cerevisiae*) were prepared following the method used by Yuliana *et al*. (2017). The culture was transferred from MRS agar to MRS broth and incubated for 24 hrs at 37°C, then propagated to obtain a concentration of 10^6 CFU/mL working starter. The culture of *S. cerevisiae* was prepared by homogenizing 1 g of instant yeast in 100 mL of sterile distilled water.

2.2 Fermentation of sweet potatoes

Cleaned sweet potato slices were placed into fermenters containing a solution of 1% sugar and 3% salt. These materials were subjected to 2 days of fermentation at room temperature with each 5% (v/v) starter with a cell density of 10^6 cells/mL of *Lb. plantarum*; *Lc. mesenteroides*; a mixed starter of *Lb. plantarum* and; *Lc. mesenteroides*; and a mixed starter of *Lb. plantarum, Lc. mesenteroides,* and *S. cerevisiae*. A container without the addition of a starter was also prepared for natural fermentation. Additionally, non-fermented sweet potato slices were also prepared as a control.

2.3 Production of sweet potatoes flour

The fermented and control sweet potato slices were washed, drained, and then dried in a convection oven (British Foyer) at a temperature of 60°C for 24-30 hrs. After 24 hrs, the trays with the samples were taken out of the oven at regular intervals, quickly weighed, and then returned to the oven. When there were no apparent changes in three consecutive weights were observed, the drying was considered completed. The dried slices were then milled using a grinder (Rulb Fanc) and strained through an 80-mesh sieve. The flour were placed in containers with tight plastic lids for storage. Some samples were taken for the determination of the final moisture content according to the method of AOAC (2000). The moisture content range of ±6-8 % was achieved.

2.4 Preparation of composite flour

Mixtures made from 50% of control and fermented sweet potato flour and 50% of wheat flour were made using a mixer (Philips) for 5 mins. These composite flour were then divided into a portion saved for pasting property observation and a portion prepared for making composite noodles.

2.5 Pasting properties

The pasting properties consisting of initial pasting temperature, rate of viscosity changes, peak viscosity, and breakdown were achieved using Brabender Micro Visco-Amylograph with the procedure described by Nurdjanah *et al*. (2017) with slight modification as follows: The suspension of starch (6%, w/w, db) was kept at 50°C for 1 min for equilibrating, then the temperature was slowly raised to 92°C at the rate of 1.5°C/min. After the temperature reached 92°C, it was held constant for 15 mins, then lowered to 50°C at the rate of 1.5°C/min, and held at 50°C for10 mins.

2.6 Preparation of composite noodles

The noodles were prepared using the Yadav *et al*. (2014) method with a modification on the proportion of sweet potato flour. The homogeneous dough was prepared by mixing a blend of 65% sweet potato composite flour (SPF and wheat flour with 1:1 ratio), 8%

https://doi.org/10.26656/fr.2017.7(1).712

eggs, 25% water, and 2% salt, using a mixer for 5 mins. The dough was then kneaded until it became smooth and elastic, rested for 5 mins, and then inserted into a rolling press machine five times to form sheets with 1.5 - 2 mm thickness. Each dough sheet was rested for 5 mins and transferred into the noodle maker to form noodle strands. Noodles were then dried in the convection oven at 60°C for 3 hrs. Finally, the textural qualities, cooking properties, and sensory properties of the composite noodles were observed.

2.7 Textural properties of composite noodles

The textural properties of cooked noodles were investigated with a Texture Analyzer (TA-XT2, Stable Micro Systems, Surrey, UK) following the method of Subarna *et al*. (2012). Textural parameters included cohesiveness, elasticity, adhesiveness, and elongation. Elongation value in percentage was obtained by calculating the time it took for the noodle strand on the probes to break with a probe spacing of 2 cm and a probe speed of 0.3 cm/s.

2.8 Cooking properties of composite noodles

The cooking properties of noodles (cooking time, cooking loss, solid loss, swelling index, and water absorption) made from different composite flour were determined according to Tan *et al*. (2009) with a slight modification. The cooking loss, swelling index, and water absorption referred to cooking quality, indicating the capacity of the noodles to maintain their shape and acceptable texture after cooking (Rita *et al*., 2020). The optimum cooking time was determined through a crushing test where cooked noodles were crushed between two glass plates until the hard cores in the noodle strands were fully hydrated. The cooking loss and cooked weight of noodles were measured after extending the cooking period 1 min longer than the optimum cooking time. Total cooking loss, which included solid loss and soluble loss, and water absorption were calculated using the following equations:

$$Cooking\ Loss\ (\%) = \frac{W_0 \times DM \times W_2}{W_0 \times DM} \times 100\%$$

$$Solid\ Loss\ (\%) = \frac{W_3}{W_0 \times DM} \times 100\%$$

$$Soluble\ Loss\ (\%) = \frac{W_4}{W_0 \times DM} \times 100\%$$

$$Water\ Absorption\ (\%) = \frac{W_1 - W_0}{W_0} \times 100\%$$

DM was the dry matter ratio of crude samples. W_0 was the initial weight of cut, uncooked noodles. W_1(g) was the weight of cooked noodles after being strained through a nylon mesh sieve. W_2(g) was the constant weight of the cooked product after being pre-dried and dried in the oven at 110°C. W_3(g), and W_4(g) were the dry matter content of sediment and supernatant, respectively, of a cooking and rinsing water combination after being centrifuged at 4500 rpm for 10 mins.

2.9 Sensory properties of dried composite noodles

The sensory evaluation of dried composite noodles was conducted for colour and overall acceptability of appearance. Approximately 6 cm long dried noodle strands were put in coded plastic trays presented on tabletops. A panel of thirty members was then requested to evaluate the colour and general acceptability of the dried noodles by scoring (1 = extremely dislike, 7 = extremely like).

2.10 Statistical analysis

This study used a Complete Randomized Block Design (CRBD) in one factorial with four replications. The significance and the differences among treatments were determined by the Analysis of Variance and Duncan test at a 5% level.

3. Results and discussion

3.1 Pasting properties

The pasting properties of composite fermented sweet potato flour are presented in Table 1. Fermentation increased peak viscosity, breakdown, setback value, and final viscosity. The temperatures at beginning of composite fermented SP flour gelatinization were close to that of control composite SP flour, but their pasting (maximum viscosity) temperatures were slightly lower than that of the control composite SP flour. Some extent of starch hydrolysis that happened during fermentation might result in a lesser rigidity of starch granules in SP, thus causing instability and disruption upon heating and stirring.

Acid and enzyme actions during the fermentation process increase the erosion of the granules (Díaz *et al*., 2018), and enzyme invasion could result in extensive branching and chain length shortening of starch (Guo *et al*., 2019). The ability of *Saccharomyces cerevisiae* to modify the microstructure of starch granules has been studied (Reyes *et al*., 2016). Thus, the change of structure in starch granules may lead to a change in the pasting properties of fermented SP flour.

The peak viscosity values of composite fermented SP flour were higher than that of the control, with LbLcSc-treated composite fermented SP flour being the highest. Peak viscosity is an indication of the starch granules' water-binding capacity. Maximum viscosity is obtained during starch gelatinization (Gulu *et al*. 2019) indicating the capacity of the starch to swell easily. Higher peak viscosity values observed in composite

https://doi.org/10.26656/fr.2017.7(1).712

Table 1. Pasting properties of composite SP flour

Treatments	Beginning of gelatinization (◦C)	Peak viscosity (BU)	Temp at maximum viscosity (◦C)	Final viscosity (BU)	Breakdown (BU)	Setback (BU)
Control	74.20±0.35	231.5±6.36	92.90 ±0.14	304±9.89	46±1.41	146±8.49
Spontaneous	76.35±0.35	435.5±0.71	91.65±0.21	578±5.66	46.5±2.12	239±8.49
Lb	75.40±0.57	432±5.66	90.95±0.14	548.5±3.40	99.5±0.71	124±0.40
Lc	75.75±0.07	559.5±1.41	88.00±0.28	540.5±0.71	150.0±0.0	137.5±9.19
LbLc	74.95±0.07	476±7.07	91.00±0.28	621±4.24	58.5±4.95	262±7.07
LbLcSc	75.40±0.57	509.5±10.67	91.20±0.28	645±10.56	65±0.00	267±6.36

Values are presented as mean±SD of two determintations. Lb: *Lactobacillus plantarum*, Lc: *Leuconostoc mesenteroides*, Sc: *Saccharomyces cerevisiae*

fermented SP flour than that of composite non-fermented SP flour are believed to be influenced by the lower rigidity of starch granules in fermented SP flour, which consequently eased the swelling process of the starch.

The low structural rigidity of starch granules in fermented SP flour causes the flour to become less resistant to distortion and have less constancy during heating. Higher breakdown viscosity values mark the sample's ability to tolerate heating and shear force during heating less (Ashogbon and Akintayo, 2013). Consequently, composite fermented SP flour had higher breakdown values compared to composite non-fermented SP flour. A similar effect of fermentation on peak viscosity and breakdown viscosity was expressed in previous studies (Oloyede *et al*. 2016; Yuliana *et al*. 2017; Yuliana *et al*. 2018). The findings suggested that improved breakdown value caused by fermentation treatment would facilitate more effortless cooking but with less resistance to stress. Samples treated with LbLc and LbLcSc had low breakdown values, while others had moderate breakdown values. These results imply that composite SP flour with LbLc and LbLcSc treatments would be less susceptible to stress than other samples.

The composite fermented SP flour had a higher setback and final viscosity values than those of the control, except for samples treated with Lb and Lc with slightly lower values. Setback and final viscosities are believed to correlate with the amylose content of the starch (Ai and Jane, 2015; Woo *et al*., 2015). During cooling, an interaction of amylose with other starch molecules occurs, contributing to the network structure and response to the setback viscosity (Ai and Jane, 2015). Furthermore, the re-association of the starch granules and the gel structure's development contributes to the final viscosity (Ortega-Ojeda *et al*., 2004).

This study shows that samples with a mixed starter of LbLc treatment and a mixed starter of LbLcSc treatment had the highest final viscosity and setback values, suggesting higher gel stability than others. Pasted starch that exhibits a high setback value on cooling is thought to result in a decent noodle quality. Yi *et al*. (2020) observed that setback value positively correlated with the springiness of noodles.

3.2 The textural qualities of composite noodles

High elasticity, low adhesiveness, and a high percentage of noodle elongation are among the parameters of good-quality noodles. Table 2 shows that fermentation treatments improved cohesiveness, elongation, as well as elasticity. It also reduced the adhesiveness of Lc-treated composite SP noodles ($p < 0.05$). Significant changes in elasticity, adhesiveness, and elongation occurred in composite fermented SP noodles with mixed starter treatments of LbLc and LbLcSc. These changes could be due to the altered

Table 2. Cohesiveness, elasticity, adhesiveness, and elongation of composite SP noodles

Treatments	Cohesiveness (gs)	Elasticity (%)	Adhesiveness (gs) (-)	Elongation (%)
Control	0.59±0.02^{a}	70.89±8.28^{a}	13.58±1.78^{b}	79.58± 14.52^{a}
Spontaneous	0.64±0.01^{bc}	76.98±4.78^{ab}	14.18±1.36^{b}	83.93±33.73^{ab}
Lb	0.64±0.04^{bc}	77.61±7.62^{ab}	13.76±1.66^{b}	100.46±18.83^{b}
Lc	0.62±0.03^{b}	75.26±8.39^{ab}	13.40±1.61^{b}	118.31±18.04^{b}
Lb Lc	0.67±0.03^{c}	76.65±10.73^{ab}	18.33±3.24^{a}	132.94±15.19^{d}
Lb Lc Sc	0.64±0.02^{bc}	82.16±6.87^{b}	14.32±1.01^{b}	134.36±8.41^{d}
Wheat	0.68±0.04	84.96±6.17	37.23±3.63	221.33±20.90
Commercial noodle	0.70±0,01	84.99±1.73	39.36±00	282.83±21.53

Values are presented as mean±SD. Values with different superscript within row are significantly different ($p<0.05$) by Duncan test. Lb: *Lactobacillus plantarum*, Lc: *Leuconostoc mesenteroides*, Sc: *Saccharomyces cerevisiae*

https://doi.org/10.26656/fr.2017.7(1).712

characteristics in the pasting profiles of the SP flour used as the main ingredients.

The paste viscosity highly correlates with the eating qualities of cooked noodles (Sandhu *et al*., 2010; Li *et al*., 2017; Li *et al*., 2019; Yi *et al*., 2020). Alterations in starch structure resulted in changes in the texture quality of noodles, as reported previously on germinated rice (Chung *et al*., 2012) and cowpea flour (Ritika *et al*. 2016). In this study, structural changes in starch granules as the effect of fermentation had altered the properties of natural starch, leading to differences in the pasting properties between fermented SP flour and the control (without fermentation), as discussed in the pasting properties section above. The utilization of composite fermented SP flour accounted for an increase in the elasticity, adhesiveness, and elongation of noodles.

The elasticity of noodles is related to the starch gel elasticity level after being gelatinized, as hinted by the starch or flour expansion rate. A study by Liao and Wu (2017) revealed that fermentation increased the expansion rate of fermented sweet potato starch. Thus, fermentation increases starch gel elasticity, giving the final product more elasticity. Moreover, in the fermentation process, protein solubility is reduced, followed by improved textural properties of noodles, as evaluated previously in traditional Thai rice noodles (Satmalee *et al.,* 2017) and Indica rice noodles (Li *et al*., 2019).

3.3 Cooking properties of composite noodles

Table 3 presents the cooking properties (cooking time, cooking loss, solid loss, swelling index, and water absorption) of noodles made from different composite flour. Fermentation treatment decreased cooking time, cooking loss, solid loss, soluble loss, and water absorption of noodles ($p<0.05$). Mixed starter treatments yielded better results than other starters, in line with other parameters observed in this study.

Fast cooking time, low cooking loss, little solid loss in the cooking water, and low soluble loss are the criteria for good noodles (Yadav *et al*., 2014; Xin *et al*., 2018). The cooking times of the samples in this study ranged from 3.91 to 4.13 mins, with LbLc and LbLcSc treatments showing minimum value. These cooking times were significantly shorter than that of the control sample, with 4.38 mins ($p<0.05$). The structure of fermented SP flour is less rigid compared to the non-fermented SP flour; it allows better moisture penetration and therefore leads to faster cooking time.

Fermentation also significantly reduced cooking loss, soluble loss, and solid loss ($p<0.05$). The lowest cooking loss value was obtained by the sample with a mixed culture of LbLc treatment (11.82%), but it was still higher than the cooking loss value of wheat noodles (7.64%). The lowest soluble loss was found in samples with spontaneous fermentation and single starter treatments of Lb and Lc.

Cooking loss indicates noodles' resistance to disintegration upon cooking (Tan *et al.,* 2016). For this reason, noodles with minimum cooking loss are preferred as few solids are wasted during cooking. There are previous reports on the reduction in cooking loss after fermentation treatments on noodles (Wan *et al*., 2011; Zhu *et al*., 2019) and pasta (Odey and Lee, 2020).

Water absorption of the composite noodles ($p<0.05$) declined with fermentation, but it remained higher than that of wheat noodles. The lowest value was 0.64±0.07%, found in the sample treated with a mixed culture of LbLcSc. Water absorption illustrates the degree of noodle hydration and may influence the noodles' eating value (Huh *et al*., 2019). Insufficient water absorption results in noodles with a compact and coarse texture, while excess water uptake makes noodles too soft and sticky. To achieve functional properties similar to those of wheat noodles, primarily in water absorption, various substances such as gluten, curdlan, and hydroxypropyl methylcellulose could be added (Xin *et al*., 2018; Huh *et al*., 2019) when SP flour is used as the main ingredients for noodles.

Table 3. Cooking properties of composite noodles

Treatments	Cooking time (Min)	Cooking loss (%)	Solid loss (%)	Soluble loss (%)	Water absorption (%)
Control	4.38±0.10^{a}	15.52±0.99^{a}	16.06±1.39^{a}	9.68±0.44^{a}	1.61±0.05^{a}
Spontaneous	4.13±0.10^{b}	12.95±2.26^{b}	14.54±1.16^{b}	5.86±0.41^{c}	1.04±0.12^{b}
Lb	4.06±0.1^{c}	13.37±0.92^{ab}	13.24±1.82^{bc}	5.69±0.63^{c}	0.78±0.12^{c}
Lc	4.00±0.18^{c}	11.38±2.97^{c}	13.42±1.50^{bc}	5.53±0.32^{c}	0.81±0.12^{c}
Lb Lc	3.91±0.06^{d}	11.82±2.73^{c}	13.19±1.37^{bc}	6.31±0.29^{b}	0.81±0.12^{c}
Lb Lc Sc	3.97±0.06^{cd}	13.75±2.56^{ab}	13.07±1.34^{bc}	6.51±0.55^{b}	0.64±0.07^{d}
Wheat	3.00	7.64	11.42	5.04	0.24

Values are presented as mean±SD. Values with different superscript within row are significantly different ($p<0.05$) by Duncan test. Lb: *Lactobacillus plantarum*, Lc: *Leuconostoc mesenteroides*, Sc: *Saccharomyces cerevisiae*

https://doi.org/10.26656/fr.2017.7(1).712

3.4 Sensory characteristics of dried composite noodles

The results of sensory evaluation on colour and overall acceptance of the dried composite noodles are shown in Table 4. Fermentation improved colour saturation and the panellist's overall acceptance of the dried composite noodles ($p<0.05$). The colours (score > 4.0) and overall acceptance (3.99-4.90) of all dried composite fermented SP noodles were preferable compared to that of the control. However, the scores were lower than all-wheat noodles, with 6.45 for colour and 6.37 for overall acceptance.

Higher favorability of the colours of the fermented noodles than that of the control is contributed to fermentation. Reduced protein and sugar levels during a lactic acid fermentation process will result in a brighter noodle colour because it minimizes the browning process (Yuliana *et al*., 2018). Moreover, there is a minimum amount of oxygen in anaerobic fermentation. Polyphenol oxidases (PPOs), the enzyme responsible for enzymatic browning, use oxygen as an electron acceptor to oxidize diphenol compounds (Taranto *et al.,* 2017). Thus, less oxygen means less browning.

Table 4. Sensory quality of dried composite SP noodles

Treatments	Colour	Overall acceptance
Control	2.37±0.22[d]	2.53±0.43[d]
Spontaneous	4.39±0.28[c]	3.99±0.22[c]
Lb	4.78±0.17[b]	4.62±0.29[b]
Lc	4.78±0.34[b]	4.90±0.07[b]
Lb Lc	4.80±0.19[b]	4.68±0.22[b]
Lb Lc Sc	4.87±0.21[b]	4.73±0.29[b]
Wheat	6.45±0.17[a]	6.37±0.10[a]

Values are presented as mean±SD. Values with different superscript within row are significantly different ($p<0.05$) by Duncan test. Lb: *Lactobacillus plantarum*, Lc: *Leuconostoc mesenteroides*, Sc: *Saccharomyces cerevisiae*

4. Conclusion

The substitution of natural sweet potatoes for fermented sweet potatoes significantly enhanced the peak, final, and setback viscosity values of the composite flour; improved the textural qualities, cooking qualities, colour scores, and overall acceptance scores of the composite noodles. Thus, fermentation has beneficial effects on the pasting properties of composite sweet potato flour and the quality of its composite white salted noodles. This study recommends composite fermented sweet potato flour treated with either a mixed culture of *Lb. plantarum, Lc. mesenteroides*, and *S. cerevisiae* or a mixed culture of *Lb. plantarum* and *Lc. mesenteroides*.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The research work was funded by *Hibah Strategis Nasional* from the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia.

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