DYNAMICS OF FUNCTIONAL PROPERTIES OF MAIZE FLOURS FERMENTED WITH LACTIC ACID BACTERIA (LAB)-CONSORTIUM ISOLATED FROM CEREALS

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Abstract: The dynamics of functional properties of maize fermented with lactic acid (LAB) consortium from cereals were evaluated. Maize was processed into flour and fermented with LAB-consortium isolated from maize and sorghum in the following combination *Lactobacillus plantarum* WCFS1 + *Lactobacillus rhamnosus* GG, ATCC 53/03 + *Lactobacillus nantensis* LP33 + *Lactobacillus fermentum* CIP 102980 + *Lactobacillus reuteri* DSM 20016, and *Pediococcus acidilactici* DSM 20284 + *Lactobacillus fermentum* CIP 102980 + *Lactobacillus brevis* ATCC 14869 + *Lactobacillus nantensis* LP33 + *Lactobacillus plantarum* WCFS1 respectively and then naturally to determine their effect on the functional properties of maize. The result showed a gradual decrease in bulk density with increasing fermentation period from 0.82 ± 0.02 g/mL to 0.80 ± 0.03 g/mL (natural fermentation), from 0.82 ± 0.02 g/mL to 0.79 ± 0.03 g/mL (LAB-consortium from maize fermentation) and from 0.82 ± 0.02 g/mL to 0.78 ± 0.03 g/mL (LAB-consortium from sorghum fermentation). The swelling capacity decreased from 0.31 ± 0.03% (0 h) to 0.20 ± 0.03% (48 h), from 0.31 ± 0.03% (0 h) to 0.18 ± 0.02% and from 0.31 ± 0.03% to 0.19 ± 0.01% in natural, LAB-consortium from maize and LAB-consortium from sorghum fermentation respectively. Water holding capacity decreased from 1.5 ± 0.03 mL/g to 0.2 ± 0.03 mL/g (naturally fermentation), from 1.5 ± 0.03 mL/g to 0.4 ± 0.02 mL/g and from 1.5 ± 0.03 mL/g to 1.0 ± 0.03 mL/g in LAB-consortium from maize and LAB-consortium from sorghum fermentation respectively. Oil holding capacity (OHC) increased significantly ($p<0.05$) with increase in the fermentation periods from 8.00 ± 0.03 mL/g to 9.50 ± 0.02 mL/g (natural fermentation), 8.00 ± 0.03 mL/g to 9.80 ± 0.03 mL/g (LAB-consortium from maize fermentation) and from 8.00 ± 0.03 mL/g to 9.73 ± 0.03 mL/g (LAB-consortium from sorghum fermentation). The least gelation concentration ranged from 3.0% in the unfermented sample to 6.0% in the various fermentation products. The variations differ significantly ($p<0.05$) with the unfermented sample. Emulsion capacity (EC) of the maize flour sample increased with increasing fermentation period from 41.03 ± 2.48% to 59.02 ± 2.44% (naturally fermentation), from 41.03 ± 2.48% to 62.12 ± 3.10% and from 41.03 ± 2.48% to 61.34 ± 2.10% in LAB-consortium from maize and LAB-consortium from sorghum fermentation respectively. This suggests the potentials of LAB-consortia fermentation in improving nutritional and functional properties of maize flour.

Keywords: Functional properties, maize flour, fermentation, LAB-consortium.

Introduction

Maize (*Zea mays*) belongs to the family of grasses (*Poaceae*) and is cultivated globally as one of the most important cereal crops (Ranum *et al.*, 2014). Maize contains approximately 72% starch, 10% protein, and 4% fat, supplying an energy density of 365 Kcal/100g and is grown worldwide, with the United States, China, and Brazil being the top three maize-producing countries (Ranum *et al.*, 2014; Gwirtz and Garcia, 2014). Maize is not only an important source of nutrients for human, but also a vital constituent in formulation of animal feed. It is also a raw material for manufacture of many industrial products and can be processed into a wide range of foods, snacks and beverages (CWFS, 2013; Sanni and Adesulu, 2013).

Maize (*Zea mays*) is an important cereals which serves as major source of carbohydrate, protein and calorie. However bioavailability is low due to the presence of anti-nutritional factors such as phytic acid, polyphenols and tannins (Maidala *et al.*, 2013). Maize contains high amount of starch and its digestibility is greatly influenced by plant type, physicochemical characteristics of the starch as well as composition, processing and storage conditions (Singh *et al.*, 2012; Olanipekun *et al.*, 2015).

Fermentation is one of the processes that decreases the level of anti-nutrients in food grains and increases the starch and protein digestibility as well as nutritive value (Singh *et al.*, 2012) and leads to an increase in protein content, enhancement of carbohydrate accessibility, improvement in amino acid balance, decrease in anti-nutritional factors like tannin and phytic acid (Singh *et al.*, 2012). Fermented food has many beneficial products metabolized by bacteria such as biomass proteins, amino acids, vitamins, minerals, flavor and aroma compounds as well as carbohydrate. Products of respiratory and biosynthetic pathways such as lactic acid, ethanol, acetaldehyde and pyruvic acid are also produced which alters the pH of foods to levels that they control the growth of pathogenic microorganisms. This therefore enhances food safety and shelf life thus aiding in food preservation (Onyango *et al.*, 2013; Ojokoh and Bello, 2014).

Lactic acid bacteria (LAB) are a large group of closely related bacteria that have similar properties such as lactic acid production, which is an end product of the fermentation. LAB includes *Lactobacillus*, *Lactococcus*, *Streptococcus* and *Leuconostoc* species. LAB fermentation is a common way of preparing food traditionally in Africa. Some of the traditionally fermented foods in Africa include maize porridge, alcoholic beverages and dairy products. Some of the main reasons for the fermentation practice using LAB are to increase food palatability and improve the quality of food by increasing the availability of proteins and vitamins (Masood *et al.*, 2011; Huili *et al.*, 2011). Furthermore, LAB confers preservative and detoxifying effects on food as well. When used regularly, LAB fermented foods boost the immune system and strengthen the body in the fight against pathogenic bacterial infections. Thus, LAB fermentation is not only of a major economic importance, but it also promotes human health in Africa (Chelule *et al.*, 2010; Onyango *et al.*, 2013). The present study is aimed at, evaluating the effect of lactic acid bacteria (LAB)-consortium fermentation on the functional properties of maize flour.

Materials and Methods

Source of materials

White variety of maize (*Zea mays*) was bought from Mushin markets of Lagos, Lagos State, Nigeria and transported to the laboratory in clean polythene bags for analysis at Federal Institute of Industrial Research Oshodi (FIIRO) where it was identified. Lactic acid bacteria were obtained from stock previously isolated from fermenting maize and sorghum. All the chemicals used were of analytical grade (AR).

Sample preparation

The raw grains of the maize were freed of foreign materials, washed with clean tap water and rinsed with distilled water. The samples were dried with hot air oven (GL, England) at 60^{O}C for 8 h. The dried samples were milled into powder using milling machine (CNC, Germany) disinfected with 70% ethanol and stored in clean air tight containers at 4^{O}C for further use (Singh *et al.*, 2012).

Inoculum preparation

Five (5) lactic acid bacteria previously isolated from each of fermenting maize and fermenting sorghum were combined as follows, *Lactobacillus plantarum* WCFS1 + *Lactobacillus rhamnosus* GG, ATCC 53/03 + *Lactobacillus nantensis* LP33 + *Lactobacillus fermentum* CIP 102980 + *Lactobacillus reuteri* DSM 20016, for consortium from maize; and *Pediococcus acidilactici* DSM 20284 + *Lactobacillus fermentum* CIP 102980 + *Lactobacillus brevis* ATCC 14869 + *Lactobacillus nantensis* LP33 + *Lactobacillus plantarum* WCFS1, for consortium from sorghum. These were grown in a 250 ml Erlenmeyer flasks containing 210 ml MRS broth respectively, and incubated for 48 h in an orbital shaker incubator (REMI/396LAG) at 37^{o}C for the inoculum to build-up. The inocula were harvested by centrifugation at 5000 g for 10 min and maintained in fresh MRS broth before fermentation. The washed cells were diluted using sterile distilled water to obtain 0.5 McFarland, standard (Dajanta *et al.*, 2009).

Fermentation of maize flours

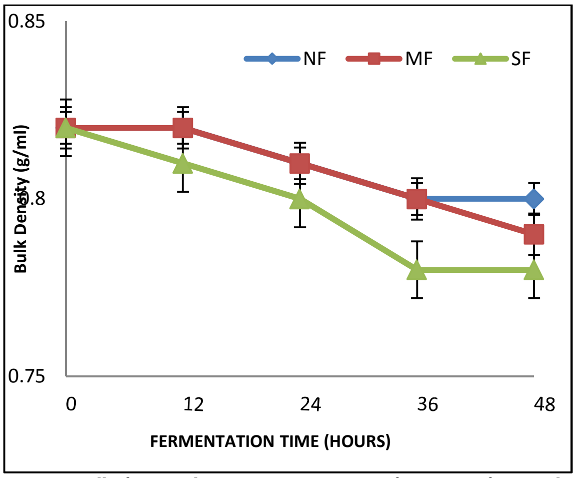
Fermentation was carried out following a modification of the method described by Sigh *et al.* (2012). The flour samples were mixed with sterile distilled water (1:2 w/v). Exactly 500 g each of the maize flours was mixed with 1000 mL of distilled water in sterile fermentation containers with the addition of 0.5 g/L potassium sorbate (to inhibit fungal growth and other contaminating organisms). The mixture was inoculated with 10 ml of 10^8 cells/mL (measured using McFarland standard) of the mixture of the lactic acid bacteria suspension and allowed to ferment. One of the set-ups was also allowed to ferment naturally without addition of potassium sorbate and starter organisms. Samples were withdrawn at 12 h intervals at periods of 0, 12, 24, 36 and 48 h for analysis.

Determination of functional properties

Bulk density was determined according to the method given by Chau and Huang (2003). Water holding capacity (WAC) and oil holding capacity (OHC) was determined according to the method described by Singh *et al.* (2012). Swelling capacity of the flour was determined according to the method given by Robertson *et al.* (2000). The gelation properties of the flour under study were determined with the method described by Aremu *et al.* (2008). The emulsion activity of the various flours was determined using the method of described by Suresh and Samsher (2013).

Results and Discussion

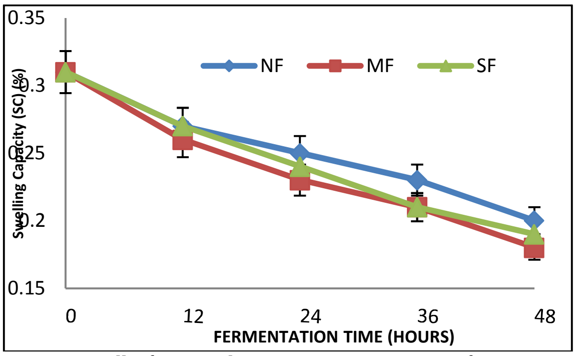
The effect of fermentation on the bulk density of maize is presented in Figure 1. Bulk density decreased gradually with increasing fermentation period. In natural fermentation, it decreased from 0.82 ± 0.02 g/mL (0 h) to 0.80 ± 0.03 g/mL (48 h), from 0.82 ± 0.02 g/mL (0 h) to 0.79 ± 0.03 g/mL (48 h) in sample fermented with LAB-consortium from maize and from 0.82 ± 0.02 g/mL (0 h) to 0.78 ± 0.03 g/mL (48 h) in the sample fermented with LAB-consortium from sorghum. The variations in the bulk density of the samples do not differ significantly (p>0.05). The report of the present investigation is in agreement with the work of Singh *et al.* (2012) who reported a gradual decrease in bulk density of maize from 0.72 ± 0.00 g/ml to 0.60 ± 0.01 g/ml and from 0.69 ± 0.00 to 0.61 ± 0.01 in sorghum after 36 hours of fermentation. Adebowale and Maliki (2011) reported a gradual decrease in BD in the range of 0.80 to 0.63 g/ml with increasing fermentation period of pigeon pea flours which are comparable to the values obtained in the present investigation. Bulk density is a measure of the load the flours can carry if allowed to rest directly on one another and decrease in bulk density is desirable in preparation of infant foods; fermentation has been reported as a traditional means of preparing low density weaning foods (Desikachar, 1980; Singh *et al.*, 2012). The density of processed products dictates the characteristics of its container or package product density influences the amount and strength of packaging material, texture or mouth feel as noted by Adebowale and Maliki (2011) and Wilhelm *et al.* (2004).



NF = Naturally fermented, MF = LAB-consortium from maize fermented; SF = LAB-consortium from sorghum fermented; Values are mean of triplicate determination.

Fig. 1: Effect of fermentation on the bulk density (g/ml) of maize flours

The effect of fermentation on the swelling capacity (SC) of maize flours is presented in Fig 2. The result shows that swelling capacity decreased with increasing fermentation period gradually. It decreased from 0.31 ± 0.03% (0 h) to 0.20 ± 0.03% (48 h), from 0.31 ± 0.03% (0 h) to 0.18 ± 0.02% and from 0.31 ± 0.03% to 0.19 ± 0.01% in natural, LAB-consortium from maize and LAB-consortium from sorghum fermentation, respectively.

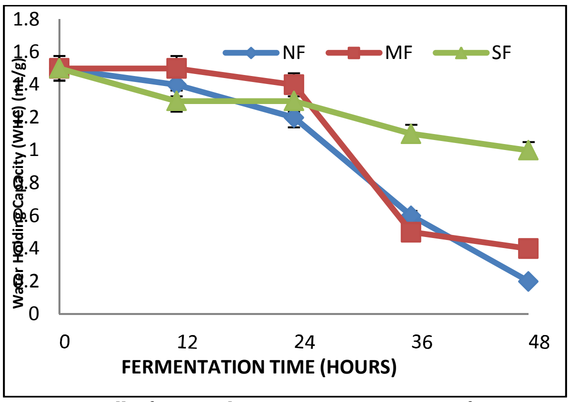


NF = Naturally fermented, MF = LAB-consortium from maize fermented; SF = LAB-consortium from sorghum fermented; Values are mean of triplicate determination.

Fig. 2: Effect of fermentation on the swelling capacity (SC) (%) of maize flours

The variations in the swelling capacity of the samples differ significantly ($p<0.05$) when compared between unfermented and fermented samples. The decrease in the swelling capacity in this study during fermentation agreed with the reports of Adebowale and Maliki (2011) and Singh *et al.* (2012) who reported decrease in SC with increasing fermentation in sorghum, millet, sorghum and pigeon pea, respectively.

The result of the water holding capacity (WHC) of maize flours showed a decreasing trend with increasing duration of fermentation (Fig. 3). It decreased from 1.5 ± 0.03 mL/g in the raw sample to 0.2 ± 0.03 mL/g in naturally fermented sample. The decrease ranged from 1.5 ± 0.03 mL/g to 0.4 ± 0.02 mL/g and from 1.5 ± 0.03 mL/g to 1.0 ± 0.03 mL/g in samples fermented with LAB-consortium from maize and LAB-consortium from sorghum respectively. The variations in water holding capacity of the samples differ significantly ($p<0.05$) when compared between unfermented and fermented samples at 48 h.

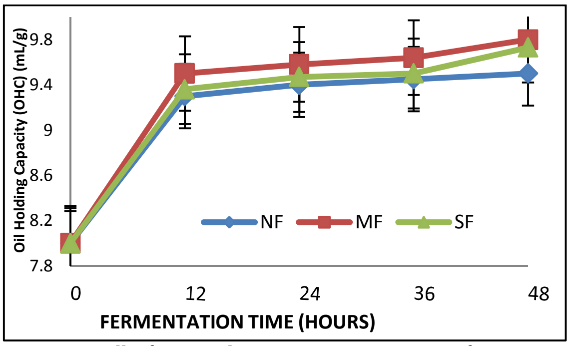


NF = Naturally fermented, MF = LAB-consortium from maize fermented; SF = LAB-consortium from sorghum fermented; Values are mean of triplicate determination.

Fig. 3: Effect of fermentation on the water holding capacity (WHC) (mL/g) of maize flours

Water holding capacity was found to be highest in unfermented sample (1.5 ± 0.03 mL/g) followed by LAB-consortium from sorghum fermented sample (1.0 ± 0.03 mL/g) and LAB-consortium from maize fermented sample (0.4 ± 0.02 mL/g) while the naturally fermented sample was the least (0.2 ± 0.03 mL/g) after 48 h. The variations in water holding capacity of the samples differ significantly ($p<0.05$) when compared between unfermented and fermented samples. Beugre *et al.* (2014) reported increase in water absorption capacity from 1.2 - 1.8 ml/g in maize which disagrees with the present study. The report of decrease in WHC of maize and sorghum flours from 0.92-0.77 ml/g and 1.26-1.03 ml/g respectively reported by Singh *et al.* (2012) is consistent with the present study. Also, Elkhalifa *et al.* (2005) reported decrease in WHC after fermentation of sorghum for 8-24 h. Gernah *et al.* (2011) and Ocheme *et al.* (2015) noted increase in water absorption capacity of maize and sorghum after malting and germination respectively. The result of this study is also comparable to the work of Adebowale and Maliki (2014) who reported decrease in WHC of pigeon pea from 142.0 g/100g to 113.0 g/100g after a 5-day fermentation. Water binding capacity is a useful indication for the incorporation of flours into aqueous food formulation especially those involving dough. WHC gives an indication of the amount of water available for gelatilization and low absorption capacity is desirable for making thinner gruels as reported by (Singh *et al.*, 2012). The result of this study suggests that the fermented flours may find application in preparation of weaning foods and in the production of some baked products (Singh *et al.*, 2012). Also, LAB-consortium fermentation of achieving low water absorption for maize flours.

The result of oil holding capacity (OHC) of maize flour under study increased significantly ($p<0.05$) with increase in the fermentation periods. It increased from the initial value of 8.00 ± 0.03 mL/g in the raw sample to 9.50 ± 0.02 mL/g in natural fermentation, from 8.00 ± 0.03 mL/g to 9.80 ± 0.03 mL/g in LAB-consortium from maize fermented sample and from 8.00 ± 0.03 mL/g to 9. 73 ± 0.03 mL/g in LAB-consortium from sorghum fermented sample (Figure 4). The variations in Oil holding capacity (OHC) of the samples differ significantly ($p<0.05$) when compared between unfermented and fermented samples. The increase in OHC was found to be highest in maize fermented with LAB-consortium from maize (9.80 ± 0.03 mL/g), followed by LAB-consortium from sorghum fermented sample (9.73 ± 0.02 mL/g) and the naturally fermented sample (9.50 ± 0.03 mL/g) while the unfermented sample was the least (8.00 ± 0.03 mL/g). This suggests the effectiveness of the LAB-consortia in improving the OHC more than the natural fermentation. The variations in Oil holding capacity (OHC) of the samples differ significantly ($p<0.05$) when compared between unfermented and fermented samples. Singh *et al.* (2012) reported that fermentation increased the OHC in the range of 8.0 to 9.7 for sorghum, millet and maize which is in agreement with the present investigation. The result of this study is also comparable to the report of Acuña *et al.* (2012) for soybean. Elkahlifa *et al.* (2005) reported about 7% increase in the oil absorption capacity of sorghum fermented for 8 h. The increase in the OHC suggests that the flours could be useful in food formulation and fortification where an oil holding capacity is a factor (Singh *et al.*, 2012). The water and oil binding capacity of food protein is dependent on the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity. The ability of the proteins of these flours to bind with oil makes it useful in food system where optimum oil absorption is desired. This makes flour to have potential functional uses in foods such as sausage production (Suresh and Samsher, 2013).



NF = Naturally fermented, MF = LAB-consortium from maize fermented; SF = LAB-consortium from sorghum fermented; Values are mean of triplicate determination.

Fig. 4: Effect of fermentation on the oil holding capacity (OHC) (mL/g) of maize flours

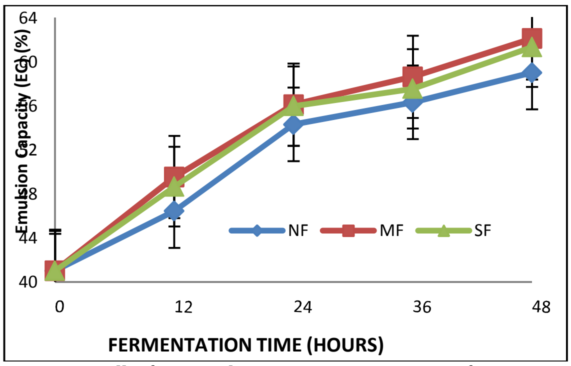
The least gelation concentration of maize flours ranged from 3.0% in the unfermented sample to 6.0% in the various fermentation products (Table 1). The variations differ significantly (p<0.05) with the unfermented sample. Gelation power is an index of gelling tendency of sample and it is an important factor in food preparations (Adebowale and Maliki, 2011). In the present study the least gelation concentration decreased with increasing fermentation period. In the maize flours, it ranged from 3.0% in the unfermented sample to 6.0% in the various fermentation products. The variations differ significantly (p<0.05) with the unfermented sample. Adebowale and Maliki (2011) also reported decrease in gelation power with increasing fermentation time in pigeon pea which agreed with the present investigation. The variations in the gelation capacities of the present investigation could be attributed to the relative ratios of different constituents such as proteins, carbohydrates and lipids that make up the flours which suggest that interactions between the various components may have a significant impact on the functional properties of the products (Adebowale and Maliki, 2011).

Table 1: Effect of fermentation on the least gelation concentration of maize flour under study

Flour Conc. (%)	0 h	12 h			24 h			36 h			48 h		
	F*	NF	MF	SF	NF	MF	SF	NF	MF	SF	NF	MF	SF
1.0	V	V	V	V	V	V	V	V	V	V	V	V	V
2.0	V	V	V	V	V	V	V	V	V	V	V	V	V
3.0	G	V	V	V	V	V	V	V	V	V	V	V	V
4.0	G	V	G	G	V	V	V	V	V	V	V	V	V
5.0	G	G	G	G	V	G	G	V	G	G	V	G	G
6.0	G	G	G	G	G	G	G	G	G	G	G	G	G
7.0	G	G	G	G	G	G	G	G	G	G	G	G	G
8.0	G	G	G	G	G	G	G	G	G	G	G	G	G
9.0	G	G	G	G	G	G	G	G	G	G	G	G	G
10.0	G	G	G	G	G	G	G	G	G	G	G	G	G
LGC	3.0^{a}	$5.0^{b,d}$	$4.0^{a,b}$	$4.0^{a,b}$	6.0^{c}	$5.0^{b,d}$	$5.0^{b,d}$	$6.0^{c,d}$	$5.0^{b,d}$	$5.0^{b,d}$	$6.0^{c,d}$	$5.0^{b,d}$	$5.0^{b,d}$

F* = Unfermented sample; NF = naturally fermented; MF = fermented with LAB consortium from maize; SF = fermented with LAB consortium from sorghum; V = viscous; G = gel; LGC = Least gelation concentration; Values with the same superscript are not significantly difference (P>0.05)

The result of the emulsion capacity (EC) of the maize flour sample increased with increasing fermentation period. The EC of maize increased from 41.03 ± 2.48% (0 h) to 59.02 ± 2.44% (48 h) in naturally fermented sample, from 41.03 ± 2.48% (0 h) to 62.12 ± 3.10% (48 h) in LAB-consortium from maize fermented sample and from 41.03 ± 2.48% (0 h) to 61.34 ± 2.10% (48 h) in LAB-consortium from sorghum fermented sample. The variations in the emulsion capacity of maize compared favourably between the naturally fermented, LAB-consortium from maize and LAB-consortium from sorghum fermented samples but do not show significant different statistically (p>0.05) except 48 h LAB-consortium from maize fermented sample which differ significantly with the 48 h naturally fermented sample. However, the values obtained for EC in fermented maize differ significantly (p<0.05) when compared with the unfermented maize sample from 12 h to 48 h (Fig. 5). The different values obtained for the fermented product differ significantly (p<0.05) when compared with the unfermented samples in each substrate from 24 h to 48 h. However, the increases do not differ significantly (p>0.05) when compared between naturally fermented, LAB-consortium from maize and LAB-consortium from sorghum fermented samples. The values obtained in the present study are comparable to the work of Suresh and Samsher (2013) who reported 43.88% and 41.48% in wheat and rice flours respectively. Difference in the EC of the various samples may be related to solubility proteins as noted by Suresh and Samsher (2013). Hydrophobicity of protein has been attributed to influence their emulsifying properties (Kaushal *et al.*, 2012).



NF = Naturally fermented, MF = LAB-consortium from maize fermented; SF = LAB-consortium from sorghum fermented; Values are mean of triplicate determination.

Fig. 5: Effect of fermentation on the emulsion capacity (EC) (%) of maize flours

Conclusion

The functional properties of maize flours improved after natural fermentation, LAB-consortium from maize and LAB-consortium from sorghum fermentation. The highest improvements were observed more in the consortia fermented samples than the naturally fermented samples. These suggest the possible use LAB-consortium fermentation isolated from cereals as starter organisms in improving the nutritional qualities of local staple cereal products.

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Conflict of Interest

The authors have declared no conflict of interest.

References

Acuña SPC, González JHG & Torres IDR 2012. Physicochemical characteristics and functional properties of vitabosa (*mucuna deeringiana*) and soybean (*glycine max*) *Características físico-químicas e propriedades funcionais de vitabosa(Mucuna deeringiana) e soja* (*Glycine max*). *Ciênce and Tecnol. Aliment., Campinas,* 32(1): 98-105.

Adebowale OJ & Maliki K 2011. Effect of Fermentation Period on The Chemical Composition and Functional Properties of Pigeon Peas (*Cajanus cajan*) Seed Flour. *Inter. Food Res. J.,* 18(4): 1329-1333.

Aremu MO, Olaofe O, Akintayo ET & Adeyeye EI 2008. Foaming, Water Absorption, Emulsification and Gelation Properties of Kersting's Groundnut (*Kerstingiella geocarpa*) and Bambara Groundnut (*Vigna subterranean*) Flours as Influenced by Neutral Salts and Their Concentrations. *Pak. J. Nutr.,* 7 (1): 194-201.

Aremu MO & Ibrahim H 2014. Mineral Content of Some Plant Foods Grown in Nigeria: A Review. *Food Sci. Qual. Man.*, 29: 73-81.

Beugre GAM, Yapo BM, Blei SH & Gnakri D 2014. Effect of Fermentation Time on the Physico-Chemical Properties of Maize Flour. *Inter. J. Res. Stud. Biosci.*, 2(8): 30-38.

Chau CF & Huang YL 2003. Comparison of the chemical composition and physicochemical properties of different fibers prepared from the peel of *Citrus sinensis L. cv. Liucheng*. *J. Agricult. Food Chem.*, 51: 2615–2618.

Chelule PK, Mbongwa HP, Carries S & Gqaleni N 2010. Lactic acid fermentation improves the quality of amahewu, a traditional South African maize-based porridge. *Food Chem.,* 122: 656–661.

CWFS, 2013. High Level Panel of Experts (HLPE). 2013. Biofuels and food security. A report by the High Level Panel of Experts on food security and nutrition of the Committee on World Food Security. Rome. http://www.fao.org/ Accessed December 10, 2015.

Dajanta K, Chukeatirote E, Apichartsrangkoon A & Frazier RA 2009. Enhanced Glycine production of fermented soybean products by *Bacillus* species. *Acta Biologica Szegediensis.*, 53 (2): 93-98.

Desikachar HSR 1980. Development of weaning food with high calories density and low hot paste viscosity using traditional technologies. *Food Nutr. Bull.,* 2: 21-23.

Elkhalifa AEO, Schiffler B & Bernhardt R 2005. Effect of fermentation on the functional properties of sorghum flour. *Food Chem.,* 92: 1-5.

Gernah DI, Ariahu CC & Ingbian EK 2011. Effects of malting and lactic fermentation on some chemical and functional properties of maize (*Zea mays*). *Am. J. Food Technol.*, 6: 404-412.

Gwirtz JA & Garcia-Casal MN 2014. Processing maize flour and corn meal food products. *Ann. New York Acad. Sci.,* 1312: 66-75.

Huili P, Guangyong Q, Zhongfang T, Zongwei L, Yanping W & Yimin C 2011. Natural populations of lactic acid bacteria associated with silage fermentation as determined by phenotype, 16S ribosomal RNA and *recA* gene analysis. *System. & Appl. Microbiol.,* 34(3): 235-241.

Kaushal P, Kumar V, Sharma HK 2012. Comparative study of physico-chemical, functional, anti-nutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*), pegion pea (*Cajanus cajan*) flour and their blends. *LWT-Food Sci. Technol.,* 48: 59-68.

Maidala A, Doma UD & Egbo LM 2013. Effects of Different Processing Methods on the Chemical Composition and Antinutritional Factors of Soybean [Glycine max (L.) Merrill]. *Pak. J. Nutr.,* 12(12): 1057-1060.

Masood MI, Qadir MI, Shirazi JH & Khan IU 2011. Beneficial effects of lactic acid bacteria on human beings. *Crit. Rev. Microbiol.*, 37(1): 91–98.

Ocheme OB, Adedeji OE, Lawal G & Zakari UM 2015. Effect of Germination on Functional Properties and Degree of Starch Gelatinization of Sorghum *Flour. J. Food Res.,* 4(2): 159-165.

Ojokoh A & Bello B 2014. Effect of Fermentation on Nutrient and Anti-nutrient Composition of Millet (*Pennisetum glaucum)* and Soyabean (*Glycine max)* Blend Flours. *J. Life Sci.*, 8(8): 668-675.

Olanipekun BF, Otunola ET & Oyelade OJ 2015. Effect of Fermentation on Antinutritional Factors and in Vitro Protein Digestibility of Bambara Nut (*Voandzeia subterranean* L.). *Food Sci. Qual. Man.*, 39: 98-112.

Onyango CA, Ochanda SO, Mwasaru MA, Ochieng JK, Mathooko FM & Kinyuru JN 2013. Effects of Malting and Fermentation on Anti-Nutrient Reduction and Protein Digestibility of Red Sorghum, White Sorghum and Pearl Millet. *J. Food Res., 2* (1): 41-49.

Ranum P, Pe˜na-Rosas JP & Garcia-Casal MN 2014. Global maize production, utilization, and consumption. *Ann. New York Acad. Sci.*, 1312: 105–112.

Robertson GL, Monredon FD, Dysseler P, Guillon F, Amado R & Thibault JF 2000. Hydration properties of dietary fibre and resistant starch: a European collaborative study. *Lebensm. Wiss. –Technol.,* 33: 72–79.

Sanni AI & Adesulu AT 2013. Microbiological and physico-chemical changes during fermentation of maize for *masa* production. *Afr. J. Microbiol. Res.*, 7(34): 4355-4362.

Singh A, Yadav N & Sharma S 2012. Effect of fermentation on physicochemical properties & in vitro starch and protein digestibility of selected cereals. *Int. J. Agric. Food Sci.,* 2(3): 66-70.

Suresh C & Samsher C 2013. Assessment of functional properties of different flours. *Afr. J. Agri. Res.,* 8(38): 4849-4852.

Wilhelm LR, Dwayna AS & Gerand HB 2004. Introduction to problem solving skills, In: Food and process engineering technology. ASAE. p.76.