PAPER NAME

Nixtamalization Application as A Quality Improvement of Corn Flour

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WORD COUNT

6347 Words

CHARACTER COUNT

32873 Characters

PAGE COUNT

14 Pages

FILE SIZE

1.2MB

SUBMISSION DATE

Jul 26, 2022 3:17 PM GMT+7

REPORT DATE

Jul 26, 2022 3:19 PM GMT+7

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Cite as: AIP Conference Proceedings **2085**, 020037 (2019); https://doi.org/10.1063/1.5095015
Published Online: 21 March 2019

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Nixtamalization Application as A Quality Improvement of Corn Flour

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Abstract. The corn is very potential to be processed as a flour and a starch material in food industry as a food ingredients and other industries. However, the functional properties of corn flour are less favored to be applied in processed products because of its unpleasant texture and short shelf life due to its fat content. One way to improve its quality is by nixtamalization process, it is a process of boiling the corn grains in lime water followed by soaking for several hours, then washing and milling to forming a dough. The purpose of this study was to evaluate the effect of nixtamalization on corn flour physicochemical properties and rheology. The experiments were prepared by a single treatment, with variation nixtamalization/ immersion duration in lime solution (control, 8, 16, 24, and 32 hours). This treatment was repeated 3 times. The results indicated that the nixtamalization time had an effect on the corn flour proximate value and rheology, the protein content increased (3.1766% - 4.4055%) and the moisture content increased (6.9986% - 8.3217%), however the fat content decreased (4.5179% - 3.2317%) and ash content decreased (1.6674% - 1.3558%) as an increasing nixtamalization time. In general, the corn flour paste characteristics are gelatinization were changed as the nixtamalization time increased, the initial temperature decreased (84.4 ^{o}C - 80^{o}C), the maximum viscosity decreased (136 BU - 123 BU), and the paste stability decreased (14 BU – 6 BU), but its reverse viscosity increased (69 BU – 120 BU). The different nixtamalization period had no effect on the formation of corn starch gel. The corn flour dough expansion volume increased as the nixtamalization time increased, and the structure of corn starch granules is changed/damaged as the nixtamalization time increased.

INTRODUCTION

The corn is one of the economic value cereals and has the opportunity to be developed because of its position as the main source of carbohydrates and proteins after rice. Based on the chemical composition and nutritional content, corn has good potential as food and industry raw materials. Corn can be processed into semi-finished products, namely corn flour [1]. Corn in the form of flour is more flexible to be processed into various processed products and in accordance with the demands of a practical all-modern life, it has longer shelf life, serviceable, can be enriched with nutrients (fortified), and mature faster [2]. Carbohydrate contents in corn can reach 80% of all dry matter, and most are in the endosperm. Carbohydrates in the form of starch are generally a mixture of amylose and amylopectin. Therefore, corn is very potential if processed into semi-finished products, namely corn flour.

The 4th Regional Conference on Chemical Engineering (RCChE 2018)
AIP Conf. Proc. 2085, 020037-1–020037-13; https://doi.org/10.1063/1.5095015
Published by AIP Publishing. 978-0-7354-1815-8/$30.00

Corn flour can be obtained by grinding corn kernels. In principle, milling of corn seeds into flour is a process of pericarp, endosperm, and embryo separation and is followed by a size reduction process. The fat content of corn flour in this dry process reached 5.42%. The fat content in corn is less preferred for processes production because it causes rancid. In addition, corn flour made by dry method has not good rheological properties characteristics. The rheological properties characteristics includes the power of dough growth, paste stability, and the ability to decompose. This rheology is related to the flour viscosity. Corn flour processed by dry method is not good for a dough because it does not contain gluten. Corn flour is also susceptible to poor retro gradation and paste stability [3].

Corn flour characteristics can be improved by modified its rheology, nixtamalization is one method for flour characteristics improvement. Nixtamalization is a process carried out to lose cell tissue and gelatinize some starch granules so that corn processed with nixtamalization will form a homogeneous and elastic paste when grinded or crushed with a grinder [4; 5]. Nixtamalization is done by cooking or boiling and soaking in an alkaline solution. Boiling process using lime solution can reduce fat content in flour because fat reacts with alkaline lime and produces soap. Thus, the fat content in corn flour can be reduced, so that the shelf life of corn flour can be extended. The treatment of calcium hydroxide can improve the nutritional value of corn by increasing and providing lysine in the glutelin fraction. Glutelin is a protein classified as gluten-forming protein which improve the developing power of the dough from corn flour [6]. During nixtamalization, the starch is partially gelatinized and produces very important changes on thermal, structure, and rheological properties [7].

Nixtamalization uses the alkaline solutions, the high pH solution, as an example the calcium hydroxide or $Ca(OH)_2$ which ionize into Ca^{2+} and OH^-, and will crosslinking with starch [8]. The interaction of Ca^{2+} with starch will stabilize the walls of starch granules so that the starch granules will be stronger and harder. The presence of Ca^{2+} in starch will damage the bond between starch and water molecules and form crosslinking with the amylose and amylopectin molecules present in starch [9]. The formation of crosslinking on starch polymer chains causes the better thermal conductivity, physical properties, structure, rheology, and aroma. Boiling process using lime solution can reduce fat content in flour due to the chemical reaction of fat and alkaline lime which produces soap, this is the mechanism of the reduction of the fat content in corn flour. With the reduction of the fat content in the corn, the shelf life of corn flour can be longer [10].

The duration of cooking and the duration of soaking in the nixtamalization process will affect the quality of the corn flour produced. This is because cooking and soaking are critical stages in the nixtamalization process. During cooking, Ca^{2+} ions are carried by water through a tip cap, embryo, pericarp, and most calcium is stored in the embryo [11, 12]. A good indicator of this cooking includes water absorption by seeds, ease of removing the epidermis, and seed tenderness. The quality of corn flour will also affect the quality of the products produced. But the longer the cooking process can cause corn flour to have a bitter taste, a paler color, and a decrease in crispness. Studied the long-term effects of non-seasoned cooking on tortilla chips. In this study, it was reported that there was an optimal length of nixtamalization cooking, which was 30 minutes at 90^0C. Therefore, this study will use corn nixtamalization technique with 30 minutes cooking time at 90^0C based on the optimal cooking time in the study [13,14].

Immersion in the nixtamalization process has an important role, because during the soaking process there will also be tissue easing which results in brittle bonds in the corn seeds and pericarp release. The release of corn pericarp results in the loss of some protein and fat content from corn kernels because it reacts with Calcium Hydroxide. The interaction of Ca^{2+} with starch will stabilize the walls of starch granules so that the starch granules will be stronger and harder. The presence of Ca^{2+} in starch will damage the bond between starch and water molecules and form crosslinking with the amylose and amylopectin molecules present in starch [15]. High stability corn flour has a fairly stable viscosity change, which is not decreased viscosity during heating. The effect of nixtamalization immersion time on the physicochemical properties of corn flour with varying immersion times, namely 0 (control), 8, 16, 24, and 32 hours were observed, the best soaking time was 24 hours, however this study only studied the physicochemical properties of corn flour [14].

The objectives of this study was to evaluate the effect of the nixtamalization process on the psychochemical and rheological properties of corn flour which was simulated with different $Ca(OH)_2$ solution immersion time.

MATERIAL AND METHOD

Material

The main raw material was dried corn grain DK hybrid variety. The chemicals used are pure amylose for standard curve, phenol, $Ca(OH)_2$, $K_2S_2O_3$, HgO, H_2SO_4, K_2S 4%, NaOH 50%, HCl 0.1 N standard solution , phenolphthalein indicator, NaOH 0.1 N solution standard, aquades, and other chemicals.

Equipment used includes Micro Visco-Amylo-Graphs (Merk Brabender GmbH Measurement and Control System, Type 803202), mixer, blender, scales, pots, steamer, stove, noodle producing machine, biscuit and tortilla rollers, biscuit printers, aluminum cups, porcelain cups, ovens, furnaces, desiccators, granule structure analyzes SEM (Analytical Scanning Electron Microscope, Type: JSM-6360LA, Brand: JEOL-Japan, Voltage: 10), UV-VIS Spectrophotometer, distillation device set, and other tools for chemical analysis and organoleptic test.

Methods

The experiments were arranged in a perfect randomized group design with a single treatment i.e. immersion time in lime solution (control, 8, 16, 24, and 32 hours). Each experiment is repeated 3 times. Equivalent data were tested with Barlett Test and Additional data were tested by Tukey test. The data were analyzed by means of variation to obtain the error estimator and the significance test to determine whether there is a difference between treatments.

Implementation of Research

Nixtamalization Process

The process of nixtamalization was based on previous study with the following modifications. About 2 kg of crushed ground corn (grit) was immersed in a pot containing 6 L of water and 20 g of boiled $Ca(OH)_2$ for 30 minutes [16]. The mixture was soaked in boiling water for 0, 8, 16, 24, 32 hours. After soaking, the corn was washed with water until the pH of washing water was neutral (pH about 6), then crushed with a grinding machine, dried and analyzed its psychochemical and rheological properties.

Observation

Figure 1 and Figure 2 describes the production of corn flour from the corn grain.

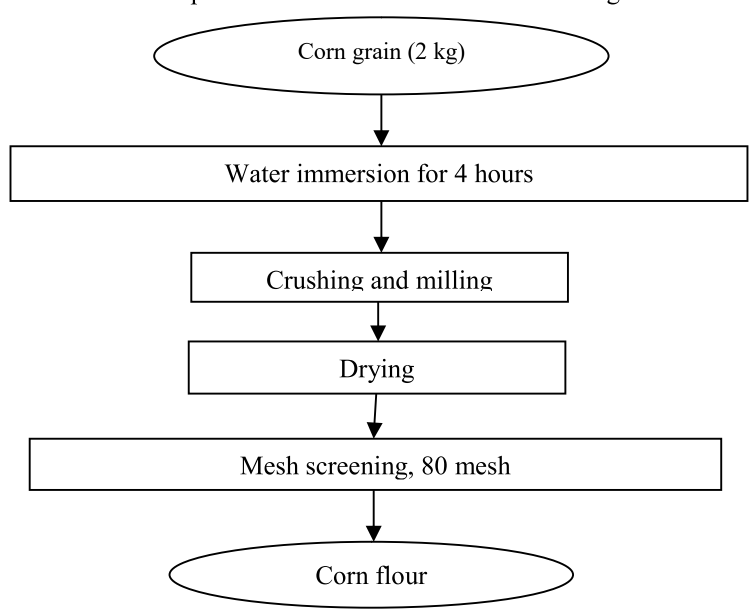

FIGURE 1. Production of corn flour with nixtamalization process [4]

The observation of nixtamalized corn flour includes the characteristics of rheological properties (paste characteristics, gel characteristics, and dough expansion volume) and the observation of proximate includes moisture content; protein levels; carbohydrate levels, fat content; and ash content. The data presented descriptively in the form of tables and graphs.

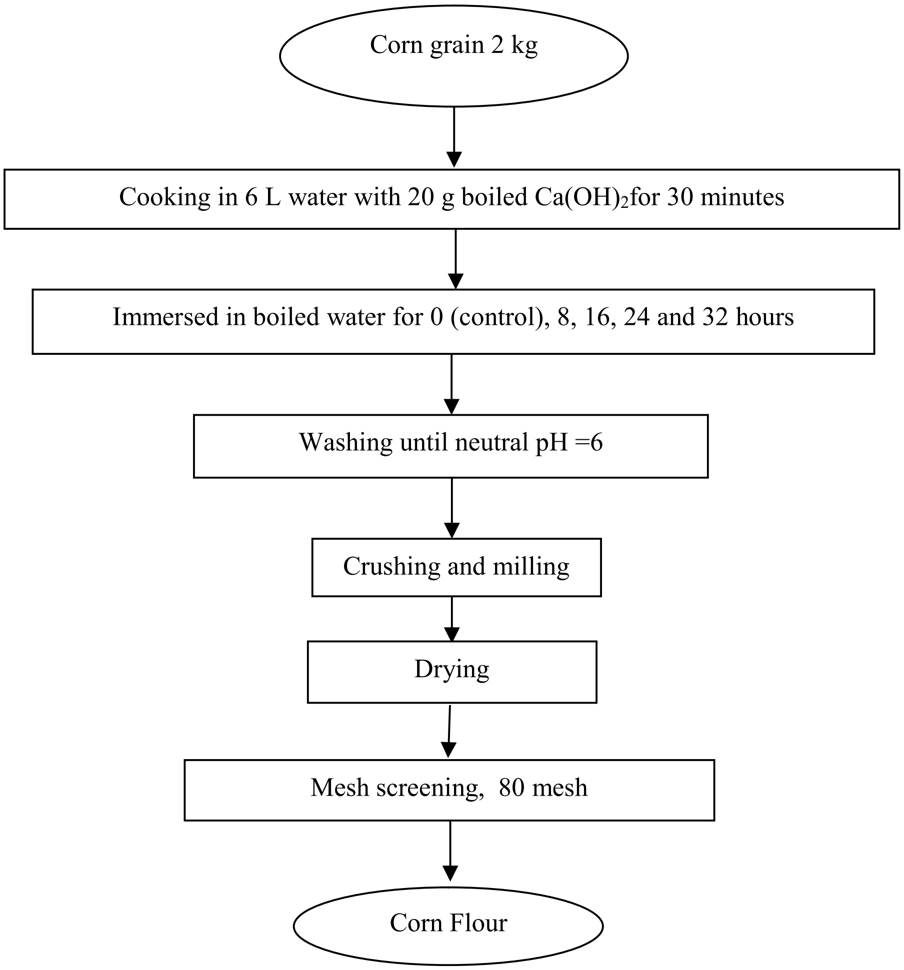

FIGURE 2. Production of corn flour without soaking in $Ca(OH)_2$ solution [3]

TABLE 1. Treatment condition

Condition	Immersion Time (Hour)
W1	0
W2	8
W3	16
W4	24
W5	32

Paste Characteristics

The analysis of the characteristics of the paste based on the Julliano method [17]. Corn flour was analyzed using Micro Visco-Amylo-Graphs / Brabender Viscograph. A 30 g of corn flour is put into a 500 mL measuring cup, then the 270 ml of distilled water was added, stirred approximately 1.5 minutes with an electric stirrer. Then it is transferred in an amylograph bowl. The measuring cup and stirrer were washed with 100 ml of distilled water, then the rinsing water is poured into the amylograph bowl. Suspension is ready for amylograph testing. The amylograph bowl is rotated at a speed of 75 rpm while the temperature is increased from 30^0C to 95^0C with a 1.5^0C per minute temperature addition. After that the temperature is maintained at 95^0C for 20 minutes, then reduced to 50^0C with a reduction rate of 1.5^0C per minute. Changes in paste viscosity were recorded continuously by Brabender Viscograf on graph paper. Observations were made on gelatinization temperature, maximum viscosity, paste stability, and reverse viscosity.

Gel Characteristics

Gel strength and hardness were measured using "Curdmeter" based on the Unliek Untoro Theory [18]. The first stage was making a flour gel. For flour gel with a concentration of 12% was made by weighing 12 g of corn flour, then the samples were put into a 200 mL glass cup, then were added with distilled water until the volume is 100 ml and stirred until a suspension were formed. The suspension was heated and stirred in boiling water until 90^0C until the gel formed. Stirring speed was 1 round per second.

The paste was poured into a plastic pipe mold with 3.6 cm diameter and 2 cm height, one of which is covered with plastic and tied with rubber. The formed gel is stored in 30^0C incubator for 24 hours. After the plastic was opened, the gel is ready to be measured. Gel measurements are carried out by the placing on a support plate which can be moved up and down. The support plate is moved upward until the gel is pressed by a load attached to it. If the gel is broken, the support plate movement is stopped. In this testing, the operational conditions of the equipment are set as 1 inch / 7 second support plate speed, suppressing plate number 11.3 in diameter, spring weight 200 g, and load weight of 200 g. Gel strength and hardness were calculated according to Eqs. (1) and (2).

$$Gel\ strength = h_2 . \frac{F_2}{S} .980\ erg / cm^2 \tag{1}$$

$$Gel\ hardness = \frac{h_1}{h_2 - h_1} . \frac{k}{L} dyne / cm^2 \tag{2}$$

Where *h1* is high curve at time t1 (cm), *h2* is high peak curve (cm), *F* is weighing weight (200 g), *S* is pressure plate area (1.00 cm^2), *L* = round the pushing plate (3.55 cm), and k is constant (13.066).

The Expansion Volume Power of Dough

The power of dough expansion volume was measured by a method developed by Sutikno [19], by making a suspension of 50 mL starch which in a 200 ml measuring cup. The activation of the yeast used 40 mL of 5% sugar solution and a 4 gram yeast, these solution was shaken until evenly distributed and let stand for 15 minutes before use. Each dough was added with 1 ml of active yeast, then stirred until evenly distributed. Then the mixtures were fermented for 2 hours at room temperature. The dough expansion volume is calculated by Eq. (3).

$$The\ expansion\ volume\ power\ of\ dough = \frac{A - B}{B} .100\% \tag{3}$$

where *A* is volume after fermentation (mL) and *B* is volume before fermentation (mL).

RESULTS AND DISCUSSION

Proximate Cornstarch Flour

Moisture Content

Water is an important food component that can affect the quality of the ingredients [20]. The changing of food water amount can affect food shelf life due to microbiological activity, chemical, and enzymatic processes [21]. This study applied the different corn immersion time in alkaline solution as a treatment in observing the effects on the moisture content of corn flour (Figure 3). Figure 3 describes the lowest water content found in control W1 (6.9986%), while the highest water content is in W5 (8.3217%). The longer the soaking time of corn in the alkaline solution causes the higher yield of corn flour. Water content increases as an increasing period of nixtamalization. This is because the longer time of corn nixtamalization, there will be more absorption and distribution of water [7]. According to SNI 01-3727-1995 [22], the maximum corn flour water content is 10%. Based on that standard, corn flour produced in this research is still classified as a good quality standard.

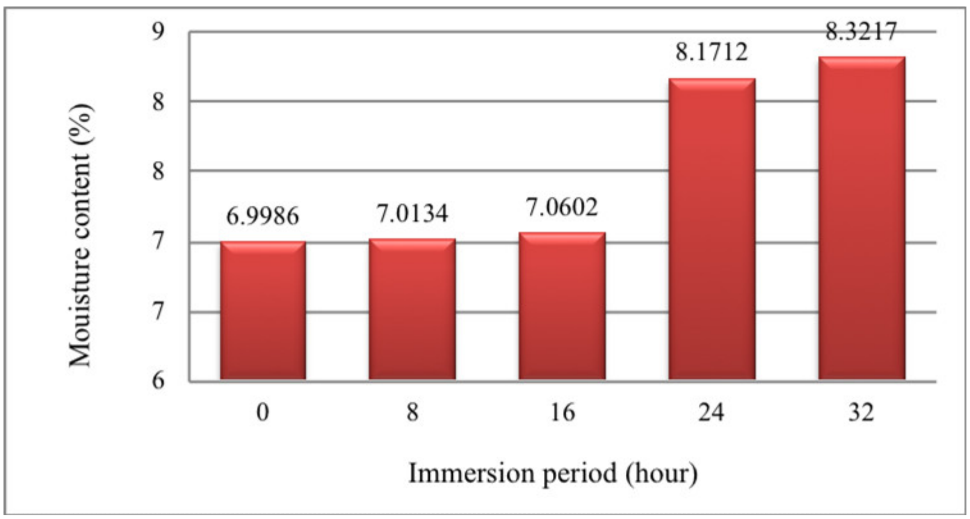

FIGURE 3. The relationship of nixtamalization period and water content of corn flour

Ash Content

Ash is an inorganic substance of residual combustion product of an organic material. The determination of ash content is related to the mineral of a material. Likewise, in the case of ash content on corn starch nixtamalization. The relationship between the duration of nixtamalization and the ash content is presented in Figure 4. Based on the results of the research, the highest ash content was found in the W1 (1.6674%) and the lowest ash content was in the W5 (1.3558%). The longer the nixtamalization process, the smaller the ash content. The ash content on corn flour should increased in line with the immersion time. This is because the longer the time of nixtamalization, the more calcium (Ca^{2+}) is absorbed into the corn.

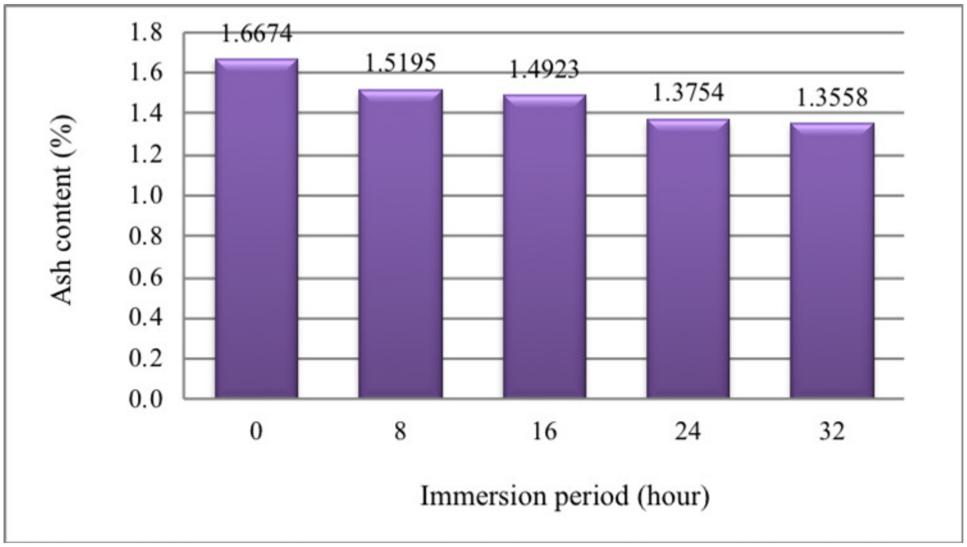

FIGURE 4. The correlation of nixtamalization period and the cornstarch ash content

However, which occurred in this study is the opposite. This was because Ca^{2+} absorbed by corn bind to fat forming soap. Therefore, it took more washing process compared to corn flour with a relatively short duration of nixtamalization. The washing process can cause the minerals in the corn flour lost which can reduce the ash content on corn flour. The natural minerals in corn (sodium, potassium, fluorine and iodine) are water soluble, which may be dissolved during the washing process. Based on SNI 01-3727-1995 [22], the maximum ash content allowed on corn flour is 1.5%. Based on the results of the research the products that meet the SNI requirements are sample immersed for 16 hour (W3), 24 hour (W4), and 32 hour (W5).

Fat Content

Fat is a group of organic bonds consisting of elements of C, H, O which have solubility in certain solvents (fat solvents). Based on the research results, the highest fat content found in treatment W1 (4.5179%) and the lowest fat content found in treatment W5 (3.2317%). The correlation between the duration of nixtamalization and fat content is described in Figure 5.

The fat content of corn starch negatively correlated to immersion time. The longer the immersion process, the less the fat content is. Boiling process using lime solution can reduce fat content in flour because the chemical reaction of fat with lime which is alkaline will produce soap [23]. These causes the fat content in corn flour decreased. As the reduction of fat content in the corn, the shelf life of corn flour can be extended.

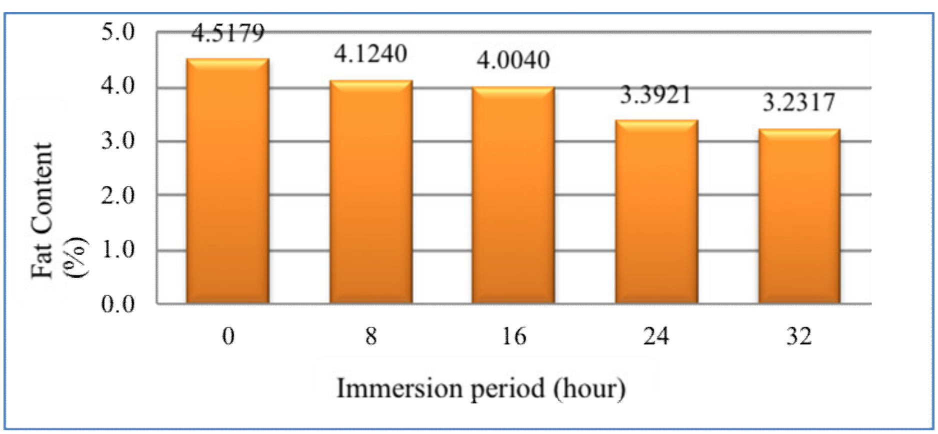

FIGURE 5. The correlation of nixtamalization period and fat content of corn flour

Protein Content

Protein is a source of amino acids contains C, H, O, and N elements that are not available in fat or carbohydrates. In this study, the objective of the measurement of protein is to determine the difference in protein levels in each treatment (Figure 6).

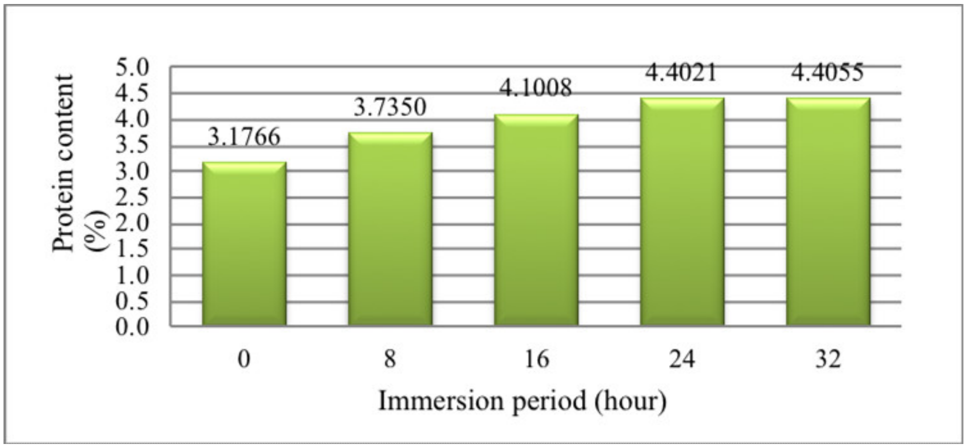

FIGURE 6. The relationship between the duration of nixtamalization and the protein content of corn flour

Figure 6 presents that the long period of immersion in nixtamalization can increase protein level in corn flour. At the treatment, the protein content in W1 only 3.18% and increased to 4.41% in W5. This is because the nixtamalization can improve the nutritional value of corn starch by increasing and providing lysine in the fraction of glutelin. Nixtamalization can enrich amino acid and probably other nutrients [24]. Corn actually has a high protein content about 6-10%, but the quality is poor because of low levels of lysine and tryptophan so that the nutritional value of corn is low. Although the amount of protein has decreased due to processing, but the protein content of processed corn starch has the advantage that there is lysine in the fraction of glutelin. Previous research on maize mentioned that soaking improves lysine availability by 21% and cooking of soaked sample improves lysine availability by 68% [25].

Characteristics of Rheological Properties of Corn Flour

Characteristics of corn flour paste is described in Table 2.

TABLE 2. Characteristic of corn flour paste in each treatment

Treatment	W1	W2	W3	W4	W5
The initial temperature of gelatinization(ºC)	84.4	81.5	82.1	82.6	80
Maximum viscosity (BU)	136	131	118	97	123
Stability of the paste (BU)	14	13	3	1	6
Reverse Viscosity (BU)	69	111	147	121	120

The Initial Temperature of Gelatinization

The initial temperature of starch gelatinization is the limit temperature which almost all of the starches reaching the maximum swelling and the swelling is irreversible [26]. The initial temperature of gelatinization is the temperature at which the first viscosity begins to rise. This changing in viscosity is due to the swelling of irreversible starch granules in water, where the kinetic energy of water molecules is stronger than the appeal of starch in the starch granules that is influenced by several factors, among others by the size of amylose and amylopectin molecules and the state of the media heating [27]. There is a previous study which compared the nixtamalization process and without nixtamalization, it evaluated the effect of the concentration of $Ca(OH)_2$ addition

(0.1 – 3.9% w/v) and cooking time (15 – 85 min) of maize grain on the structural, thermal and rheological characteristics, it mentioned that the $Ca(OH)_2$ addition on the nixtamalization process causes an increase in temperature and enthalpy of gelatinization [28].

Based on the above table it is known that the initial temperature of gelatinization on cornstarch with W1 treatment has the highest gelatinization initial temperature among other treatments that is 84.4ºC. While other treatments have decreased although not form a straight line. The initial temperature of gelatinization treatment W2, W3, W4, and W5 were 81.5ºC, 82,1ºC, 82,6ºC, and 80ºC, respectively. Through nixtamalization, the initial gelatinization temperature dropped. This is because Ca^{2+} in starch breaks the bonds between starch and water molecules and form crosslinks with amylose molecules and amylopectin in starch, which also called as a calcium bridge. The formation of crosslinks in the starch polymer chain contributes to better thermal conductivity, improved physical properties, structure, rheology and aroma [29].

Maximum Viscosity

Maximum viscosity is the maximum point of the viscosity of the paste produced during the heating process. Maximum viscosity can also be called peak viscosity if after maximum viscosity achieved followed by a decrease in viscosity. Maximum viscosity is usually used as an indicator of the level of convenience of pasta to be cooked. Based on observations made with the Brabender Visco-Amylograph, the maximum viscosity of corn flour ranged between 97-136 BU, with the highest maximum viscosity value for the W1 treatment of 136 BU and the lowest for W4 treatment of 97 BU. The higher the $Ca(OH)_2$ concentration used in the nixtamalization process, the lower the maximum viscosity of the cornstarch. The crosslinking formed between Ca^{2+} ions with starchy hydroxyl groups may decrease the maximum viscosity in nixtamalized corn flour. This is because in corn flour without $Ca(OH)_2$ treatment, the amylose molecule and starch amylopectin are only supported by weak hydrogen bonds, while the higher kinetic energy of the water can enter the starch molecule and the granules become swollen.

In $Ca(OH)_2$ starch cornstarch, the starch bonds are not only weak hydrogen bonds, but reinforced by the crosslinking between starch molecules and Ca^{2+} ions. This can limit the granular swelling and may cause low maximum viscosity. While for the W5 treatment the maximum viscosity of nixtamalization cornstarch is greater than W4. This is probably because the fat content contain in corn flour is relatively small; so it increases the maximum viscosity of corn flour. The fat acting as an amylose complex will form an insoluble precipitate and the presence of this fat may inhibit the removal of amylose from the granules [30]. In other words, the less fat in the corn, the easier it will out of the granule, so the maximum viscosity of corn flour increases.

Stability of the Paste

The stability of the paste is the difference between the maximum viscosity and the initial viscosity during the cooling paste phase. The stability of the paste is also interpreted as a change in viscosity during heating at a constant temperature (95ºC). The stability of the paste will be positive if there is an increase in viscosity and it is negative when there is a decrease in viscosity. The stability of the paste is considered to be good when the difference between the maximum viscosity and the initial cooling viscosity is small. Based on the observation that has been done (Table 2) the W1 (without nixtamalization) has a level of stability that is less good among other treatments because it has the difference between the maximum viscosity and cooling phase paste initial viscosity greater among other treatments, for 16 BU. While for corn flour with treatment W2, W3, W4, and W5 have better stability than treatment W1 because they have smaller difference that is 13 BU, 3 BU, 1 BU, and 6 BU, respectively.

Generally, the difference between the maximum viscosity and the cooling phase paste initial viscosity or cornstarch breakdown without $Ca(OH)_2$ treatment was higher than corn flour with $Ca(OH)_2$ treatment. Breakdown tends to decrease with increasing concentration of $Ca(OH)_2$. This indicates that the nixtamalization treatment may cause the starch granule structure to be more stable to be cooked and less tendency in the decreasing of viscosity during cooking and stirring. The stability of the granular structure may be due to the presence of Ca^{2+} ions which bind to the starch molecule. Therefore, increasing the bond strength in the granules and decreasing the breakdown of the flour paste [13]. Study of nixtamalization using 0.125, 0.25 and 0.5% $Ca(OH)_2$ produce acceptable physicochemical, textural, quality, compositional/nutritional and pasting properties [31].

Reverse Viscosity

The reverse viscosity describes the tendency of retrogradation [32]. The lower the value of reverse viscosity, the lower the tendency of retrogradation. Retrogradation is a process of re-crystallization of the gelatinized starch [33, 34]. Based on observation using BrabenderVisco-Amylograph, the reverse viscosity of nixtamalized corn flour ranged from 69-147 BU. The smallest reverse viscosity value is in W1 treatment, whereas the largest reverse viscosity is found in W3 treatment

Based on these data, W1 treatment has a lower downward tendency. W1 treatment should have a tendency to be higher in the process, but the result in this research is the opposite. This is because the amount of cornstarch W1, the amylose molecule and the starch amylopectin are supported only by weak hydrogen bonds, meanwhile the higher kinetic energy of the water can enter the starch molecule so that the granules become swollen and cause the more exiting amylose and cause the high maximum viscosity. The large amount of amylose that comes out from the starch granules causes the re-joining of amylose into the granules through the hydrogen bonds to take place slowly, so the tendency for retrogradation is small. In corn flour W2, W3, W4, and W5, the starch bonds are not only weak hydrogen bonds, but supported by the crosslinking between starch molecules and Ca^{2+} ions. This may limit the granular swelling and produces a low peak viscosity due to less exiting amylose granules, which causes the re-joining of amylose into the granules by hydrogen bonding which occur more rapidly and has a higher tendency for retrogradation.

Gel Characteristics

The mechanism of gelatinization of starch occurs through in 3 stages [35]. First of all, the water slowly back and forth percolates into the granule. Then the granules will expand rapidly at 60-85ºC. Furthermore, if the temperature keeps rising then the starch granules will break so that the starch molecules will diffuse outward from the starch granules. This case causes a change in viscosity so as form a paste. If the hot starch paste is stirred while cooling, the viscosity of the paste will increase. Whereas if during the cooling was not stirred, there would be a tendency for the formation of intermolecular bonds between the starch molecules [36].

TABLE 3. Results of observation of gel corn starch formation

Treatment	Gel formation
W1	not able to form a gel
W2	not able to form a gel
W3	not able to form a gel
W4	not able to form a gel
W5	not able to form a gel

In this study, the corn paste was stirred during cooling, and corn paste did not form any gel due to the occurrence of the intermolecular bond required in gel formation. In addition, the process of gel formation is strongly influenced by amylose and amylopectin content in corn flour. Corn starch generally contains 25% amylose and 75% amylopectin. The flour with high amylopectin content will be difficult to form gel because the branch molecule in amylopectin will prevent the formation of intermolecular bonds. While the starch which contains amylose is easier in forming molecular bonds [36]. Furthermore, there is a probability of amylose in corn flour is modified and as a result the corn flour is not able to form a gel. This result is supported by Zobel (1988) research which referred in [37] which reported that the low gel strength in the nixtamalized corn starch in $Ca(OH)_2$ solution may be caused by Ca^{2+} ions inhibits the recrystallization of starch molecules during the gel cooling phase which causes a weak gel tissue.

The Expansion Volume Power of Dough

The expansion volume power of the dough is the ability of a material to expand in volume. Each ingredient has the ability to expand differently, depending on the level of protein (gluten) present in the ingredient. In this study, the nixtamalization period influences the power corn flour dough expansion volume. This can be seen in Figure 7.

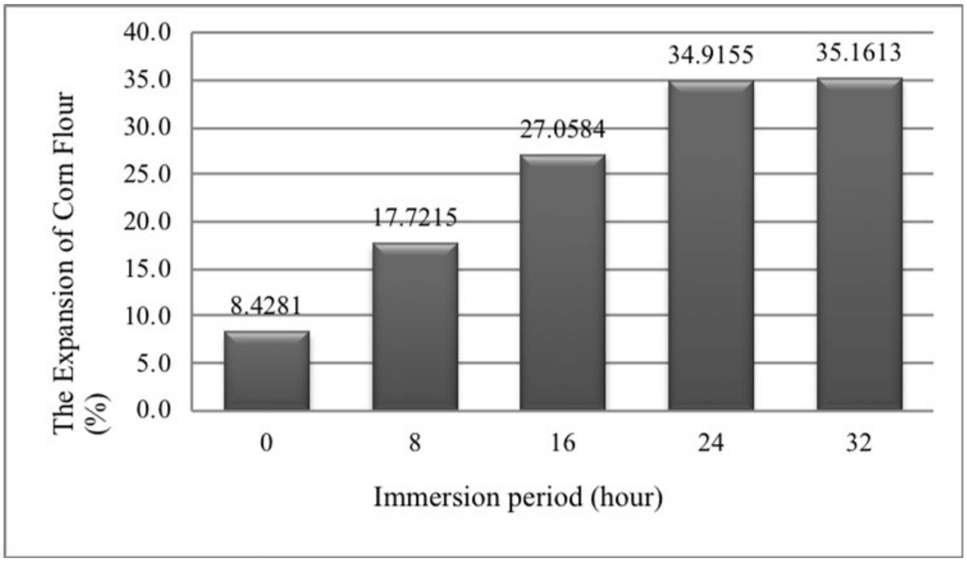

FIGURE 7. The relationship between the nixtamalization period and the expansion of corn flour dough

Based on Figure 7, it is known that the biggest dough expansion power is found in the long treatment of a 32 hour nixtamalization (W5) that is 35.1613%, while the lowest dough is found in the treatment of W1 with the 8.4281% dough expansion volume. The longer the time of nixtamalization, the bigger the volume of corn flour dough produced. This is because the nixtamalization can improve the nutritional value of corn starch by increasing and providing lysine in the fraction of glutelin [6]. Glutelin is a protein classified as a gluten-forming protein. The glutenin function is to strengthen the dough so it is able to hold, or capture CO_2 gas generated by the added yeast activity, with the result that the dough is lifted up and the volume expands.

The Structure of Nixtamalized Corn Starch Granule

The analysis on the structure of nixtamalized corn starch granules were using SEM (Analytical Scanning Electron Microscope, Type: JSM-6360LA, Brand: JEOL-Japan, Voltage: 10). The analyzes were performed for all soaking treatments W1, W2, W3, W4, and W5 at 500x, 2000x, and 5000x magnifications. Here is a picture of the structure of corn starch granules at 2000x magnification (Fig. 8).

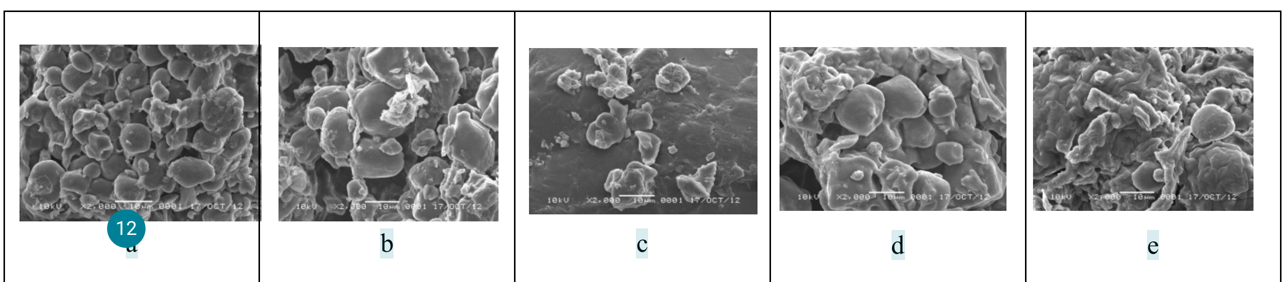

FIGURE 8. Granulated starch grain starch structure with various immersion treatments (a = 0 hour, b = 8 hours, c = 16 hours, d = 24 hours, e = 32 hours)

Figure 8 shows that the duration of immersion affects the granular shape. It appears that the granular structure is still visibly intact, as the increasing immersion time, the molecules structure is defect, so that they are not complete (Fig. 8 b, c, d, and e).

The nixtamalization by modified method using a heating treatment and continued by immersion in boiling water for 0, 8, 16, 24, 32 hours, then washed to pH of washing water, and ground. These processes cause the break of corn starch granules structure [38]. During the alkaline cooking there is a calcium concentration gradient through the pericarp structure of in the kernels, promotes physicochemical changes in the germ and endosperm, the internal anatomical structures of maize kernels, the heat and mass transfer changes and modify the kernel structure and the rheological properties [39]. There is a mass transport phenomenon during the immersion, and this step is critical because solute absorption defines the quality of the product. The alkaline solution causes the degradation and the softening of the cellular wall components of the pericarp, which acts as a physical barrier to the calcium and water diffusion [40].

CONCLUSIONS

The nixtamalization time affects the proximate and the nature of rheology of corn flour. The different immersion time, from 0 to 32 hours causes the increasing on the protein content (3.1766-4.4055%) and moisture content (6.9986-8.3217%), but it reduces the fat content (4.5179-3.2317%) and ash content (1.6674-1.3558%). The effects on the characteristics of the paste are the initial temperature of gelatinization (84.4-80ºC), the maximum viscosity (136-123 BU), and the stability of the paste (14–6 BU) of corn flour tend to decrease but increase in reverse viscosity (69–120 BU). Different duration of nixtamalization did not affect the formation of gel corn flour. The power of corn flour mixture tends to increase as an increasing nixtamalization time, and the structure of corn starch granules are altered / damaged.

REFERENCES

1. T. R. Shah, K. Prasad, and P. Kumar, Cogent Food & Agric. **2**, 1-9 (2016).
2. Suarni and I.U. Firmansyah. "Beras jagung: prosesing dan kandungan nutrisi sebagai bahan pangan pokok". in *Prosiding Seminar dan Lokakarya Nasional Jagung*, conference proceedings, edited by Suyamto (Pusat Penelitian dan Pengembangan Tanaman Pangan, Bogor, 2005), pp.393‒398.
3. Suarni, Jurnal Litbang Pertanian **28**, 63-71 (2009).
4. R. G. Moreira, X. Sun, and Y. Chen. J. Food Eng. **31**, 485-498 (1997).
5. G. Mendez-Montealvo, M.M. Shanchez-Rivera, O. Paredes-Lopez, and L.A. Bello-Perez, Int. J. Biol. Macromol. **40**, 59-63 (2006).
6. J. L. Fernandez-Munoz, et.al. J. Food. Sci. **54**, 330-336 (2004).
7. M. H. Gomez, C. M. Mc.Donough, L. W. Rooney, and R. D.Waniska, J.Food Sci. 44-42 (1989).
8. C. M. Bryant and B. R. Hamaker, Cereal Chem. **74**,171-175 (1997).
9. M. E. Rodriguez, M. Yanez-Limon, J. J. Alvarado-Gil, H. Vargas, F. Sanchez-Sinencio, J. D. C. Figueroa, F. Martinez-Bustos, J. L. Martinez-Montes, J. Gonzales-Hernandez, M. D. Silva, and L. C. M. Miranda, Cereal Chem. **73**,593-600 (1996).
10. J. L. Fernandez-Munoz, O. Zelaya-Angel, A. Cruz-Orea, and F. Sanchez-Sinencio. Anal. Sci. **17**, 338-341 (2001).
11. J. M. Carrillo, R. G. Dorado, E. D. C.Rodriguez, J. A. G. Tiznado, and C. R. Moreno, Plant Foods Hum Nutr. **59**, 35–44 (2004).
12. D. Santiago-Ramoz, J. D. Figueroa-Cardenas, R. M. Mariscal-Moreno, A. Escalante-Aburto, J. J. Veles-Media, J. Cereal Sci. **81**, 108-117 (2018).
13. G. G. Widianti, "Pengaruh Lama Nikstamalisasi Terhadap Kualitas Tortila Chips" undergraduate thesis, Universitas Lampung, 2010.
14. S. Putri, "Kajian Sifat Fisikokimia Tepung Jagung Nikstamal dan Aplikasinya Sebagai Bahan Baku Tortila Chips," Master Degree Thesis, Universitas Lampung, 2011.
15. O. R. Fennema, *Principles of Food Chemistry* (Marcel Dekker, Inc. New York, 1996).
16. R. G. Moreira, X. Sun, and Y. Chen, J. Food Eng. **31**, 485-498 (1997).
17. B. O. Julliano, *Cereal Chemistry Prosedures* (International Rice Research Institute, Los Banos, 1974), pp.269.
18. U. Untoro. "Mempelajari Beberapa Sifat Dasar dalam Pembuatan Gel dari Cincau (Prema oblongifona Merr)," (Institut Pertanian Bogor, Bogor, 1985), pp.87
19. Sutikno. "Mempelajari Berbagai Cara Ekstraksi Tepung Gadung (Dioscorea hispida Dennst) dalam Usaha Menghilangkan Racun Dioskorin," (Institut Pertanian Bogor, Bogor, 1980), pp.67.
20. K. A. Buckle, R. A. Edwards, G. H. Fleet, and M. Wootton, *Ilmu Pangan*, edited by: Purnomo H, Adiono (UI-Press, Jakarta, 1985).

21. S. Fardiaz, *Mikrobiologi Pangan* (Kerjasama Departemen Pendidikan dan Kebudayaan Dirjen Dikti dan PAU Pangan dan Gizi, Institut Pertanian Bogor, Bogor, 1989).
22. Badan Standardisasi Nasional, *Syarat Mutu Tepung Jagung* (Badan Standardisasi Nasional – BSN, Jakarta, 1995).
23. H. Martinez-Flores, M. G. G. Romo, V. J. U. Romero and J. B. Yahuaca, J Food Lipids. **13**, 177-185 (2006).
24. K. N. Waliszewski, Y. Estrada, and V. P. Waliszewski, Int J Food Sci Technol **38**, 73-75(2003).
25. P. F. Nche, M. J. R Nout, and F. M. Rombouts, Int J Food Sci Nutr. **46**, 241-246(1995).
26. O. R. Fennema, *Principles of Food Chemistry* (Marcel Dekker, Inc., New York, 1996).
27. R. Collinson, "Swelling and gelatinization of starch" in *Starch and Its Derivatives*, edited by J.A. Radley (Chapman and Hall, Ltd. London, 1968).
28. G. A. Villa, R. S. Rosiles, R. R. Villalobos, F. R. Gonzalez, J. D. D. F. Cardenas, and J. A. M. Alborez, BJAS **23 (4)**, 653–663(2017).
29. J. L. Fernandez-Munoz, A. O. Zelaya-Angel, Cruz-Orea, and F. Sanchez-Sinencio. Anal. Sci. **17,** 338-341 (2001).
30. M. Glicksman, *Gum Technology in the Food Industry*, (Academic Press. New York, 1975).
31. A. Mendez-Alborez, R. A. Martinez-Morquecho, E. Moreno-Martinez and A. Vasquez Duran, AJB, **11(85),** 15178-15187(2012).
32. D. S. Damardjati, *Amilografi Untuk Karakteristi Sifat Pasta Pati* (Balitan, Bogor, 1986).
33. F. G. Winarno, *Kimia Pangan dan Gizi* (Gramedia Pustaka Utama, Jakarta, 1987), pp.253.
34. R. E. Preciado-Ortíz, M. G. Vázquez-Carrillo, J. D. Figueroa-Cárdenas, S. H. Guzmán-Maldonado, D. Santiago-Ramos, and A. Topete-Betancourt, J Cereal Sci. **83**, 171-179, 2018.
35. Mc Cready, R. M. "Starch and dextrin" in *Method in Food Analysis*, edited by Joslyn, M.A., (Academic Press, New York, 1970).
36. Hodge, J. E. and E. M. Osman. "Carbohydrates" in *Principles of Food Science part I Food Chemistry*, edited by O. R. Fennema, (Marcel Dekker Inc, New York,1976).
37. M. Mondragon, E. M. Hernandez, J. L. Rivera Armenta and F. J. Rodriguez-Gonzales, Carbohydr. Polym. **55,** 411-418 (2004).
38. R.G. Moreira, X. Sun, and Y. Chen. J. Food Eng. **31,** 485-498 (1997).
39. E. Gutierrez-Cortez, *et.al*. J.Cereal Sci. **51,** 81–88 (2010).
40. M.G Ruiz Gutierrez, J. Food Eng. **98**, 76–83 (2010).

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