Hamaisa *et al. Journal of Ethnic Foods* (2022) 9:24
https://doi.org/10.1186/s42779-022-00140-9

Journal of Ethnic Foods

ORIGINAL ARTICLE

Open Access

Check for updates

RETRACTED ARTICLE

# Physicochemical characteristics of *jagung bose*, an ethnic staple food from East Nusa Tenggara, Indonesia

Atika Hamaisa[1], Teti Estiasih[2*], Widya Dwi Rukmi Putri[2] and Kiki Fibrianto[2]

**Abstract**

*Jagung bose* is a typical corn-based staple meal from East Nusa Tenggara Province, Indonesia, which requires a considerable boiling period due to its hardness. After storage for almost one year, this staple food is prepared from the *pena' muti' fatu* white corn variety. This study aimed to compare the physicochemical properties of *jagung bose* to whole corn of the *pena' muti' fatu* variety. Physicochemical properties analysis consisted of amino acids, functional groups, dietary fiber, proximate, crystallinity, starch granule shape, and pasting properties. In this study, the samples of *jagung bose* and corn of *pena' muti fatu* were obtained from the natives in East Nusa Tenggara. *Jagung bose* was prepared by pounding the kernel to remove the pericarp. The samples were ground and analyzed for physicochemical characteristics, and the data were analyzed by t test. The results showed that whole corn and *jagung bose* had high amylose and crystallinity and revealed an A-type starch crystal structure. The whole corn had more protein, fat, amylopectin, fiber, and ash but lower starch and amylose content than *jagung bose*. Starch granules of whole corn and *jagung bose* were polygonal shape with a smooth surface. The pericarp removal and pounding by adding some water resulted in different pasting properties. The peak, final, and breakdown viscosity and pasting and gelatinization temperatures of whole corn were higher than those of *jagung bose*. The setback viscosity of *jagung bose* was lower than that of whole corn, which meant the viscosity was maintained high during cooling. The high gelatinization temperature and crystallinity of *jagung bose* required a long cooking time.

**Keywords:** Ethnic food, Indonesia, *Jagung bose*, Pericarp, Physicochemical properties

## Introduction

Ethnic foods are the cuisine originating from the culture and heritage of a specific ethnicity. Ethnic food is a unique gastronomic source of ethnics or tribes, which differs from their national cuisine [1]. It refers to the explanation of Kwon [2] that ethnic groups or tribes went through a long history of agriculture to study their own foods; develop traditional technologies to produce foods based on their knowledge of local ingredients of plants and/or animal sources [1]. Globalization causes the spread of food across cultures so that ethnic foods in a region are often threatened their existence due to the shifting of food consumption behavior. Therefore, the preservation of ethnic food is important, one of which is scientific exploration. In some regions worldwide, some ethnicities have a specific staple food. Most Indonesian people consume rice as a staple food, although in the past, cassava and corn were also considered as the main dishes.

East Nusa Tenggara is an Indonesian region (Fig. 1) with an arid and dry environment that allows just a few crop plant species to thrive, such as various kinds of corn. Yulita and Naiola [3] reported nine varieties of corn from

*Correspondence: teties@ub.ac.id; teties@yahoo.co.id

[2] Department of Food Science and Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
Full list of author information is available at the end of the article

© The Author(s) 2022. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

**Fig. 1** East Nusa Tenggara islands (red color) at Indonesia archipelago (https://id.wikipedia.org/wiki/Berkas:East_Nusa_Tenggara_in_Indonesia.svg)

RETRACTED ARTICLE

East Nusa Tenggara with different morphology. Those varieties are *pena' taume', pena' masa', pena' [illegible]', batarlai mean, pena' pulu', pena' boto', pena' li' [illegible] batarlai mutin, pena' muti', puti, pena' muti', pena' molo' [illegible] pena' molo' 2, dan pena' molo'.* Each local variety has different properties and morphology with a different use; therefore, the people in this region still cultivate local corn varieties.

Most Indonesian people consume rice as a staple food. However, the people in some regions of East Nusa Tenggara (Kupang City, Regencies of Kupang, Timor Tengah Selatan, Timor Tengah Utara, Malaka, and Belu) have an original and traditional staple food, namely *jagung bose*. *Jagung* means corn, and *bose* in the local language means "pounded". In the eighteenth century, corn entered the island of Timor, East Nusa Tenggara, in 1789. In his writings, William Bligh recounts his experience when he and his group were being sent to ensure the existence of Dutch colony settlements on Timor Island. At that time, he, who was resting in Kupang saw a person with brownish-yellow skin color, long black hair, and who liked to chew betel nut (Fig. 2). The clothes worn by these residents are square cloth tied around the waist and tucked in a machete in the folds, a scarf as a head covering, and carrying betel nut placed in a piece of cloth tied to the four ends placed on the shoulders. The Kupang people presented him with dried turtles and local maize. Timorese (the people in Timor Island, East Nusa Tenggara) named it *pen*, which means corn [4].

Based on historical research by Kasijanto and Sihotang [5], the diversity of the people of East Nusa Tenggara can be seen from dozens of kingdoms on almost all islands, such as, the Wesei Wehali, the Oenam or Liurai Sonbai, and the Insana. Not much is known for certain about the origins of these kingdoms because some of them are stories in oral tales or myths. Myths in the NTT community have an important function because they become the basis for determining social structures and power so that they affect the traditional political and royal system. The economic system, the family system, the political system, and religion are closely related. Agriculture can be considered an economic and religious subsystem or religion in East Nusa Tenggara society associated with the agrarian mindset.

In the tradition of planting corn in East Nusa Tenggara, corn kernels are inserted into a hole with peanuts and pumpkin seeds. This typical tradition of corn farmers is called *salome*, an acronym for "one hole filled with crowds". They think that corn kernels are like to a human who cannot live alone and have a social being. Likewise, corn needs friends in its life holes, and these friends are beans and corn seeds that reflect a symbiotic mutualism. The yields of the three types of seeds are processed in one menu called *katemak* corn. Timorese has used this food to meet nutritional needs and prevent hunger. *One of the Timorese meals is katemak* corn which consists of five main ingredients: corn, pumpkin, ricebeans, peanuts, and pumpkin leaves. Another typical Timorese food is *jagung bose* (*bose* corn). This dish consists of corn, nuts such as peanuts, ricebeans, red beans, and coconut milk. *Jagung bose* means corn pounded with a mortar to remove the outer husk and

RETRACTED ARTICLE

**Fig. 2** People from East Nusa Tenggara holding corn in 1921 [5]

dirt. After pounding the corn, it is sifted to remove the remaining husk of the corn that has been peeled off, then boiled until cooked.

Based on the story of Bait and Lim, Fatumnasi Village traditional figures, in the Japanese era before Indonesia's independence, there was a *suap raja* tradition, in which people prepared food for the ruling kings. At that time, the ruling kings on the island of Timor were the king of Molo, the king of Amanatun, and the king of Amarasi. The three monarchs first ruled over the tribes scattered over the island of Timor. At that time, the only product used for food was white corn, called *pena muti* (Timor). The food given to the kings is prepared from white corn until it is cooked. The pericarp often sticks to the king's teeth when eating these foods. Therefore, the king ordered the people to peel the pericarp from the corn kernels. Peeling the corn kernels was initially done by hand, so it took a long time. Then found a way to pound the corn kernels using a stone with a hole in the middle. This pounding process continues to develop until now, using hardwood to replace stone and given a hole in the middle and named *lesung* (mortar). A pounder is a hardwood that is round and long and called *alu* (pestle). The corn that has been ground and separated from the husk is called *jagung bose* which is corn that has been ground and has no pericarp.

Based on the historical searches by Liubana and Nenohai [6], the Atoni Pah Meto people in the South-Central Timor District make *esu* (*lesung*) as equipment for processing food. *Atoni pah meto,* which means people from dry areas. *Atoni pah meto* is a Dawan tribal people who live on the island of Timor. Initially, *esu* was made of *Faut Esu* (stone mortar) stone. *Esu* is one of the main tools used by the *Atoni Pah Meto* community, which functions as a container for pounding rice or corn. Currently, *esu* is made of hard tree trunks. The tree trunk is then cut about 1 m and perforated to a depth of about 20–35 cm. In addition to the mortar, the tool used for pounding rice and corn is the *hanu* (pestle). *Hanu* is used as a rice or corn pounder. *Esu* and *hanu* can be found in every *Atoni Pah Meto* community house, especially in the villages. Every household has a plantation field that produces rice and corn as food, so people need *esu* and *hanu* to clean it. Rice and corn are ground using *esu* and *hanu* to produce ready-to-cook rice and *jagung bose* (Fig. 3).

Boineno, a women farmer group member at Naibonat Village, Kupang Regency, narrated that *jagung bose* (*pena bose*) was only served to kings and noble families in ancient times. Usually, only served at traditional ceremonies or traditional events. In the past, rice was a rare food and was only served to royal families and nobles on conventional occasions. Because the amount is minimal, white corn is served that has been ground and washed until there is no more husk. Corn that has no husk is called *jagung bose.* It is softer and resembles rice because it has been separated from the pericarp, but the amount is reduced. Therefore, *jagung bose* is only served to kings, noble families, and royal guests. While the people still eat *katemak* corn (*pena pasu*), corn that still has the pericarp.

One step in *jagung bose* preparation for consumption is by pounding the corn kernels in traditional equipment called "*lesung*" (mortar) and "*alu*" (pestle) made from wood. *Jagung bose* is processed from a local variety of corn, *pena' muti' fatu* is characterized by tough texture and long cooking time, *pena'* means corn, *muti'* means white, and *fatu* means stone. This name is derived from the characteristics of this corn which are white color and tough texture like stone (Fig. 4).

RETRACTED ARTICLE

**Fig. 3** Culture of grinding corn that has existed for a long time in East Nusa Tenggara. This picture is from [illegible] 5 [5]

This hard texture is derived from the traditional storage and preservation of *pena' muti' fatu*. After harvesting, this corn is stored in a "*rumah bulat*" or roundhouse (Fig. 5) by hanging this corn cob for almost one year above the traditional furnace for daily cooking. The arid climate of East Nusa Tenggara results in water evaporation from the corn cobs or drying the corn during storage. This drying is aggravated by heat from the furnace that the hard texture of corn might obtain from aging during storage and water evaporation. East Nusa Tenggara had an arid climate and high temperature with low relative humidity. Due to water evaporation, each starch chain, mainly amylose, is linked each other by hydrogen bonding. Aghababaei et al. [7] reported that the aging of fresh wheat grains affected gluten network structure and starch gelatinization. Nawaz et al. [8] explained that aging-induced starch granule changes and changed the cooking quality and glutinous rice stickiness.

*Jagung bose* is usually consumed with another condiment that is locally found in East Nusa Tenggara, such as *kacang nasi merah* (ricebean, *Vigna umbellata*) and *kacang turis hitam* (pigeon pea, *Cajanus cajan*) (Fig. 6). Preparation of *jagung bose* as a staple food is manual and time-consuming with traditional and simple kitchen sets. The first step is to manually remove corn kernels from its cobs after the corn cobs are stored for almost one year in the roundhouse (Fig. 5). The kernels should be sufficiently dry and hard to remove from the cobs easily. Corn kernels are then comminuted using a traditional pounder made from stone (Fig. 7). The pounding aims to remove the pericarp, and the pericarp is manually separated from the dehulled kernels by using a traditional bamboo big plate. After pounded and pericarp removal, *jagung bose* is sold in conventional markets, which is usually mixed with beans (Fig. 6).

*Jagung bose* is prepared by boiling the dehulled corn kernels for about 3 h, usually mixed with the beans. The constraint in *jagung bose* preparation as a staple

**Fig. 4** *Pena' muti' fatu* corn kernels as raw material for *jagung bose* (authors' documentation)

RETRACTED ARTICLE

**Fig. 5** Roundhouse for *pena' muti' fatu* corn cobs storage (**a**), hanging them in the roof (**b**) above the traditional furnace for daily cooking (**c**), and corncob after peeling (**d**) (authors' documentation)

**Fig. 6** Beans of *kacang nasi merah* (*Vigna umbellata*) and *kacang turis hitam* (*Cajanus cajan*) (**a**) and the mixture with *jagung bose* (**b**) (authors' documentation)

food is a tough texture that takes a long-time cooking. The cooked *jagung bose* (Fig. 8) is served with side dishes such as traditional roasted meat (*daging Se'i*) and vegetables, and sometimes it is cooked with coconut milk to produce a creamy sensation. However, the consumption of this food as a staple tends to decrease due

RETRACTED ARTICLE

**Fig. 7** Pounding of corn kernels (**a**) by traditional wooden mortar and pestle (**b**), separation of corn kernels from pericarp (**c**), *jagung bose* (corn kernel without pericarp) (**d**) (authors' documentation)

**Fig. 8** Cooked *jagung bose* mixed with beans that are ready to consume with side dishes (authors' documentation)

to the diversion into rice. Long-time preparation is the main obstacle to the consumption of this staple food.

Characterization of *jagung bose* is important to reveal the science behind the specific characteristics of this corn. The unique features of *jagung bose* need an intensive study to overcome the obstacles in its utilization, mainly long cooking time. Many parts of the world use corn as a staple food, and usually, the maize is processed in cornmeal. Variety corn is traditionally dehulled by pounding (Fig. 7a) to remove the pericarp. The characteristics of this variety also have not been studied. This study aimed to characterize the *jagung bose* corn compared to the original whole corn before processing into *jagung bose*. The physicochemical properties of whole corn and *jagung bose* (without pericarp) were studied. This characterization could be used for evaluating the hard texture and long cooking time of *jagung bose* as the basis for its quality improvement.

RETRACTED ARTICLE

## Materials and methods

### Materials

The Tunas Mekar Boentuka farmer group in South Central Timor, East Nusa Tenggara, provided the *pena' muti' fatu* local corn. The information about *jagung bose* was obtained from the interview with the traditional leaders and direct observation of its preparation at Tunas Mekar Boentuka farmer group in South Central Timor, East Nusa Tenggara. There are 21 regencies and municipalities in East Nusa Tenggara province, in which people are at four regencies (Belu, North Central Timor, South Central Timor, Kupang), and one municipality (Kupang) still consume jagung bose. South Central Timor Regency was selected as the location for interview and observation because the *pena' muti' fatu* variety for this study was cultivated in this region. Two traditional leaders in this area (Head of Fatumnasi Village, South Central Timor district, traditional leaders of Fatumnasi Village) were interviewed due to their knowledge of history and the origin of this ethnic staple food. Women farmer group Sekar Tani at Naibonat Village, Kupang Regency, cultivates *pena' muti' fatu* variety and processes this corn into *jagung bose* for sale and consumption on their own. One member of this farmer group was selected for interview because she knew well about the history and processing of *jagung bose*, and other members did not know deeply. Therefore, the participants for interview and observation were restricted based on their knowledge of the history of *jagung bose* and their habit of processing and consuming. Other traditional leaders and women farmer groups were non-participants.

Personal interviews and observations of participant were conducted with two traditional leaders from South Central Timor and one member of the women farmer group Sekar Tani at Kupang Regency. The interview of history and the processing of *jagung bose* was performed for 30–60 min. The key leading questions were about: the *jagung bose* eating habits; the origin of *jagung bose*; the variety of corn for *jagung bose* processing, starting time for *jagung bose* consumption; the origin of *jagung bose* name; the history *of jagung bose* recognition by people at East Nusa Tenggara Province; the history of *jagung bose*; and how to process *jagung bose*. The result of the interview was narratively analyzed.

Based on interview and observation, the preparation of *jagung bose* are as follows: corn was harvested in the dry season and stored for about one year on the roof of the roundhouse (*rumah bulat*) above the traditional furnace (Fig. 5). After storage, the corncobs were peeled, and the kernels were manually removed from their cobs. Corn kernels of 60 g were divided into two treatments: whole corn and *jagung bose* (without pericarp). *Jagung bose* kernels were obtained by traditionally and manually pounding the kernel to detach the pericarp. The pounding was conducted using a stone mortar and pestle (Fig. 7a). Some water was gradually added during pounding to avoid slippery. The pericarp was manually separated from the pounded *jagung bose* kernels using a woven bamboo big plate "*tampah*" (Fig. 7b). The dehulled kernels were ground into 100 mesh flour with a grinder (Getra IC-04A, China).

### Amino acids determination

The LC/MS–MS liquid chromatography system (Shimadzu, Japan) method was used to determine the amino acid composition of whole corn, and *jagung bose* flour. The MassLynx V4.1 SCN943 software was used to do the analysis. Each 50 mL screw test tube contained 2 g of whole corn, and *jagung bose* samples. The material was hydrolyzed in an autoclave at 110 °C for 12 h before being neutralized with 6 N NaOH to reach a volume of 50 mL. The sample was filtered through a 0.22 M filter, diluted 200 times with $H_2O$, and injected into the LC/MS–MS. The mobile phase contained solvent A: 0.1% pentadecafluorooctanoic acid (PDFOA) 99.5%, 0.5% water/$CH_3CN$ with 0.1% formic acid, and solvent B: 0.1% PDFOA, 10%, 90% water/$CH_3CN$ with 0.1% formic acid. Elution was based on a 6-min linear gradient program from 90% A: 10% B to 50% A: 50% B, followed by a 2 min equilibration phase to initial conditions before the next injection. The flow rate was 600 L/min, and the entire duration for analysis was 6 min.

### Functional group determination by Fourier Transform Infrared Spectroscopy

A few samples were mixed with KBr with a reflectance and incident angle of 45°. The mixture was pressed into a salt plate and put in an FTIR instrument (8400S/Shimadzu, Japan). The wavenumber was set at Instrument 400–4000/cm with a resolution of 4/cm until distinct spectra. Measurement was conducted at 25 °C. The spectra are normalized and adjusted by taking the intensity (arb units).

### Dietary fiber analysis

The total, soluble, and insoluble dietary fiber were measured using an enzymatic–gravimetric approach in a phosphate buffer system according to AOAC 985.29, 2007 [9].

### Proximate analysis

The proximate analysis consisted of analysis of protein (AOAC 992.15, 2012), fat (AOAC 922.06, 2012), water, and ash (AOAC 923.03, 2012), carbohydrate, starch, amylose, and amylopectin [10].

RETRACTED ARTICLE

#### Crystallinity analysis

The crystal structure was determined using X-ray diffraction (XRD). XRD spectra were obtained using CuK monochromatic radiation and PANalytical X'Pert3 X-Ray Diffraction Highscore plus software. At 25 °C, the wavenumber, voltage acceleration, and amperage were 1.5418A, 40 kV, and 30 mA, respectively. Whole corn and *jagung bose* flour samples were put into a cylindrical sample holder and loaded into the XRD machine. The light intensity was monitored at a 2 Bragg angle from an initial 10° angle to a final 100° angle and shown as a real-time scanning spectrum linked to the XRD equipment. Crystallinity and other essential parameters were determined from XRD analysis using system software.

#### Starch granule morphology analysis

Starch granule morphology was observed by scanning electron microscope (SEM). Whole corn and *jagung bose* flour were dehydrated in 99.6% ethanol separately and directly mounted on circular aluminum strips coated with silver paste. The sample was then gold-coated using a CS 100 sputter coater (Poland). Samples were observed and photographed on an X-act Oxford Instrument detector using AZtecOne scanning electron microscope software (FEI Quanta FEG 650 type FE-SEM) at 1000× and 2000× magnification with a 10 kV acceleration voltage.

#### Pasting properties

The amylogram curve was determined using a Rapid Visco Analyzer (RVA 4500, Perten Instrument Australia Pty Ltd., Australia). Each sample was mixed with 10 ml of distilled water to create a 10% w/w suspension. Each suspension was kept at 30 °C for 1 min before being heated to 95 °C at a rate of 12.2 °C/min for 2.5 min, and then cooled to 50 °C at 11.8 °C/min and stored for 2 min at 50 °C.

#### Data analysis

All analysis was performed in three replications, except for amino acid analysis, FTIR and XRD were analyzed twice. Statistical analysis was conducted by t test to know the statistical difference between *jagung bose* and whole corn characteristics.

### Results and discussion

#### Proximate composition and dietary fiber

Carbohydrate was the major component of whole corn and *jagung bose*, and it was dominated by starch. Whole corn and *jagung bose* contained an appreciable amount of dietary fiber, with the predominant insoluble dietary fiber (Table 1). Pounding and separating pericarp in *jagung bose* preparation increased carbohydrate slightly. This increase might relate to decreasing fat and protein. Removing pericarp by using a traditional woven bamboo plate decreased dietary fiber; thus, the carbohydrate content also decreased. However, starch content increased in *jagung bose* compared to the whole corn. According to Naves et al. [11], the corn kernel comprises four main parts: the pericarp (bran), germ (embryo), endosperm, and the tip. Chateigner-Bounty et al. [12] reported that corn pericarp consisted of approximately 70% cell wall polysaccharides composed mainly of xylose, arabinose, and glucose, a lower amount of galactose, and mannose in a trace amount, and also it contained a low amount of lignin. Whole corn had higher soluble and insoluble dietary fiber than *jagung bose*. The pericarp is composed of 50% heteroxylan [12], as part of the fiber and discarded during *jagung bose* preparation. The pericarp is rich in the dietary fiber of 30% [11] and contains an intertwined network structure mainly of heteroxylan [13], which is included in insoluble dietary fiber. Data in Table 1 show that insoluble dietary fiber was higher than soluble one. Total dietary fiber of corn was 13.1–19.6%, with insoluble and soluble corn fiber content of 11.6–16.0% and 1.5–3.6%, respectively [14]. Both insoluble and soluble dietary fiber was partly removed during *jagung bose* preparation.

Xin et al. [15] reported the carbohydrate composition of the corn kernel that comprised 13.34% neutral detergent fiber, 3.29% acid detergent fiber, 0.64% acid detergent lignin, 1.21 sugar, 69.87% starch, 86.21% total carbohydrate, and 72.88% non-fiber carbohydrate. Meanwhile, corn pericarp had starch of 11–23%, xylan of 18–28%, arabinan of 11–19%, and cellulose of 12–25%

**Table 1** Proximate and dietary fiber composition of whole corn and *jagung bose*

| Component (%, db) | Whole Corn | *Jagung Bose* |
|---|---|---|
| Protein | 5.10 ± 0.24 | [illegible].63 ± 0.2[illegible] |
| Fat* | 4.06 ± 0.29 | 1.3[illegible] ± 0.[illegible]9 |
| Moisture | 11.00 ± 0.61 | 12.[illegible]9 ± 0.04 |
| Ash* | 0.98 ± 0.0[illegible] | [illegible].39 ± 0.11 |
| Carbohydrate* | 78.86 ± [illegible].73 | 81.46 ± 0.33 |
| Starch | 58.[illegible]2 ± [illegible]7 | 62.50 ± 2.41 |
| Amylose* | 24.[illegible] ± 0.70 | 28.96 ± 0.70 |
| Amylopectin | 34.01 ± [illegible]5 | 33.54 ± 3.06 |
| Total dietary fiber* | 14.47 ± 0.14 | 10.53 ± 0.41 |
| Soluble dietary fiber* | [illegible]1 ± 0.02 | 0.58 ± 0.07 |
| Insoluble dietary fiber* | 13.26 ± 0.12 | 9.95 ± 0.34 |

*Statistically different between whole corn and *jagung bose*

[13]. The fiber of corn pericarp accounts for 41–71%. Thus, removing pericarp from the whole kernel in *jagung bose* preparation reduced the fiber and increased the starch content.

Amylopectin dominated starch of whole corn and *jagung bose* of 57.72 and 53.66%, respectively. The amylose level for both was also high compared to other corn varieties. According to Somavat et al. [16], conventional corn starch contained amylose of 25–27% and amylopectin of 73–75%. *Pena' muti' fatu* variety used to produce *jagung bose* is classified as high amylose corn. Amylose tends to have a straight polymer chain which is easier to form interchain hydrogen bonding and produces a crystalline structure. This crystallinity might occur during long storage at the *rumah bulat*, thus resulting in a hard texture. Amylopectin also contributes to the crystalline formation after nuclei formation by the amylose chains. In retrogradation, amylose and amylopectin play different roles. At the beginning of retrogradation, amylose rapidly and irreversibly reassociates to form crystal nuclei. This nucleation determines the rate of retrogradation, and long-term retrogradation occurs after nucleation. The amylose crystal nucleus interacts with the outer chain amylopectin to produce amylose crystalline regions. This interaction impacts on the formation of perfect crystallite. Nuclei formation by amylose determines crystallization rate [17]. Long-term storage at the *rumah bulat* with an arid climate and the heat from the furnace during daily cooking contributes to forming starch crystal formation. Temperature affects water evaporation and water. Donmez et al. [18] indicated that retrogradation is associated with starch and water interaction. Li and Hamaker [19] reported that storage temperature affected intermolecular starch polymer chain interactions in starch retrogradation.

Whole corn and *jagung bose* had low moisture content that prevented microbial growth. *Jagung bose* had a slightly higher moisture content than whole corn because a small amount of water was added during *jagung bose* preparation in the pounding step. Water evaporated slowly during drying by hanging the corn cobs above the traditional furnace in the roundhouse (*rumah bulat*) as the traditional place for corn storage. Fresh corn usually contains high moisture content. Li et al. [20] reported that the moisture content of corn kernel after harvesting was 2.2%, higher than before harvesting at 23.9%. Slow drying happened during corn cobs storage at the *rumah bulat*, preserving the corn for more than one year. The smoke from the traditional furnace for daily cooking might also contribute to corn preservation. This furnace uses wood as the fuel, and the wood smoke contains compounds for preservation. Zhang et al. [21] reported that more than three hundred compounds were found in smoke, dominated by phenols, followed by ketones and aldehydes. The wood used for fuel is not specified depending on the availability of the surrounding *rumah bulat*. Wood smoke reveals antioxidant and antimicrobial activity [22]. Zhang et al. [21] reported that the type of volatile organic compound in smoke was determined by cellulose, hemicellulose, or lignin decomposition.

Corn pericarp or bran is the source of good quality protein and minerals [11]. The pericarp removal during *jagung bose* preparation produced lower ash content in *jagung bose* than in whole corn. The *pena' muti' fatu* variety as the raw material for *jagung bose* contained low ash content. Paraginski et al. [23] reported ash content of colored corn about 0.88–1.3[illegible]%, and a higher mineral was found in corn pericarp of 2–5% [24]. Pericarp removal in the pounding step reduced the ash content of *jagung bose*.

Higher fat was found in whole corn than that of *jagung bose* (Table 1). During the pounding of whole corn in *jagung bose* preparation, the corn kernel was broken and the germ might release and discard. Corn pericarp contained fat of 2–3% and corn germ of 18–41% [20]. Removal of pericarp and part of germ resulted in a much lower fat content of *jagung bose*.

Corn germ protein accounts for 29% of total protein in the kernel protein. Meanwhile, corn bran contained 10–13% protein [24]. Removal of pericarp in *jagung bose* preparation also removed some protein; thus, the protein content was slightly higher in whole corn than that of *jagung bose*. *Pena' muti' fatu* variety had low protein content (Table 1) compared to colored pericarp corn varieties of 9.76–13.40% [23]. The carbohydrate of *pena' muti' fatu* variety (78.86%) was high, and this variety's fat and protein content were lower than others. Jaworski et al. [25] reported corn protein of 11.9%. Pericarp contained less protein than endosperm. According to Santiago-Ramos et al. [26], corn pericarp consisted mainly of cellulose, hemicellulose, lignin, and protein of 2.4%. It represented 3.4–9.5% of grain weight. Structurally, corn pericarp is non-uniform coated by a waxy layer. This structure consisted of three main zones: zone I was the pedicel; zone II was the germ, and zone III was the endosperm. According to Zhang [24], corn germ contained 12–21% protein. Xin et al. [27] reported that crude protein of corn germ account for 14.63%, with 2.60% neutral detergent insoluble crude protein, 0.20% acid detergent insoluble crude protein, 11.11% soluble crude protein, and 8.13% non-protein nitrogen. Therefore, the removal of pericarp contributed to lowering the protein of *jagung bose*.

Whole corn and *jagung bose* contained 18 and 17 amino acids, respectively, with slightly different concentrations (Table 2). The pericarp removal in the *jagung bose* preparation did not affect the amino acid composition. *Jagung*

RETRACTED ARTICLE

**Table 2** Amino acid composition in whole corn and *jagung bose*

| Amino acid | Concentration (mg/g sample) | | Amino acid | Concentration (mg/g sample) | |
|---|---|---|---|---|---|
| | Whole corn | *Jagung bose* | | Whole corn | *Jagung bose* |
| L-Arginine | 0.24 ± 0.043 | 0.22 ± 0.012 | L-Proline* | 0.84 ± 0.007 | [illegible] ± 0.009 |
| L-Histidine | 0.22 ± 0.020 | 0.19 ± 0.028 | L-Glutamic acid* | 1.33 ± 0.030 | 1.16 ± 0.022 |
| L-Lysine | 0.13 ± 0.032 | 0.11 ± 0.038 | L-Aspartic acid* | 0.5 ± 0.013 | [illegible] ± 0.006 |
| L-Phenylalanine | 0.33 ± 0.030 | 0.29 ± 0.006 | L-Cysteine* | 0.07 ± 0.000 | – |
| L-Isoleucine | 0.26 ± 0.000 | 0.22 ± 0.015 | L-Threonine | 0.32 ± 0.007 | 0.27 ± 0.002 |
| L-Leucine* | 0.92 ± 0.000 | 0.87 ± 0.032 | L-Serine* | 0.39 ± [illegible] | 0.32 ± 0.008 |
| L-Tyrosine | 0.09 ± 0.006 | 0.07 ± 0.007 | L-Alanine* | 0.66 ± 0.021 | 0.55 ± 0.006 |
| L-Methionine | 0.12 ± 0.004 | 0.12 ± 0.012 | L-Glycine* | 0.34 ± [illegible] | 0.29 ± 0.001 |
| L-Valine* | 0.38 ± 0.001 | 0.31 ± 0.003 | L-Tryptophan | 0.02 ± 0.001 | 0.02 ± 0.002 |

*Statistically different between whole corn and *jagung bose*

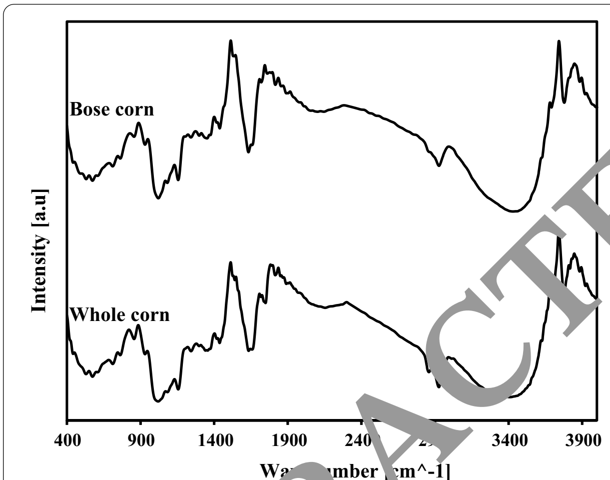


**Fig. 9** FTIR spectra of whole corn and *jagung bose*

*bose* did not have cysteine, although this amino acid was found in whole corn in very low concentrations. Corn is generally poor in lysine due to the high prolamin (zein in corn) content, a storage protein with trace amounts of lysine [28]. According to Marrufo-Diaz et al. [29], the protein of corn, zein, lack of tryptophan. Data in Table 1 show that *pena' muti' fatu* variety contained a very trace amount of tryptophan. In general, removing pericarp reduced the concentration of amino acids, except methionine, due to decreased protein.

#### Functional groups

Figure 9 demonstrates that the FTIR identified functional groups of whole corn and *jagung bose* at 500–4000 $cm^{-1}$. The 500–4000 wavenumber region is an infrared (IR) identification area which widely used in biological applications, including a representative fingerprint area for lipids, proteins, amides I/II, carbohydrates, and nucleic acids [26, 27]. The peak at 1000–1100 $cm^{-1}$ is related to starch groups with the absorption at around 996 $cm^{-1}$ (CO bending of glycosidic linkages), 1014 $cm^{-1}$ (CO stretching and COC/CO bending), and 1039 $cm^{-1}$ (CO bending) [30–32]. C-O stretching occurred in whole corn with an intensity of 10% and 15%, and a slight wavenumber shift occurred in *jagung bose* with 17% and 25% intensities. The higher starch is found in *jagung bose* than in whole corn (Table 1).

Based on the peaks of the wavenumbers of 1634 and 1658 $cm^{-1}$, whole corn C=O displayed stretching with an intensity of 36 and 37%, respectively, indicating the presence of an amide I structure. However, *jagung bose* also had peaks at 1632 and 1658, with 41 and 45% higher intensities, respectively. According to Kong and Yu [33], the amide I band with a wavenumber of 1600–1690 $cm^{-1}$ with C=O stretching is closely related to the secondary protein structure. The C=O bonds in the backbone peptide chain are the most sensitive protein secondary structure [34]. *Jagung bose* had more secondary structure than whole corn, related to pericarp removal. Amide II had 1480–1575 $cm^{-1}$ with C–H stretching and N–H bending [33]. Whole corn displayed speaks of 1437 and 1540 $cm^{-1}$ with intensities of 41 and 74%, respectively. Meanwhile, *jagung bose* had peak at 1437 $cm^{-1}$ with an intensity of 54% and did not reveal spectra around 1500 $cm^{-1}$. According to Sadat and Joye [34], the amide II band had less specificity and sensitivity for conformational protein changes. The decrease in peak intensity of amide I band in whole corn might reflect that *jagung bose* had more order protein secondary structure.

The absorbance around these wavenumbers were 2922 $cm^{-1}$ (symmetric $CH_2$ stretching), 2853 $cm^{-1}$ (asymmetric $CH_2$ stretching), and 1745 $cm^{-1}$ (carbonyl ester group stretching) [30]. The presence of peaks at these wavenumbers reflected the functional groups from

RETRACTED ARTICLE

lipid. According to Derenne et al. [35], two major distinct regions corresponded to the lipid IR spectra. The high wavenumber spectra of 3100–2800 cm$^{-1}$ contributed from C-H stretching vibrations, which originated mainly from the hydrocarbon chain. The low wavenumber region below 1800 cm$^{-1}$ was correlated to lipid polar head groups. Figure 9 shows that the intensity of the high wavenumber of 3400 cm$^{-1}$ in whole corn (12%) was higher than that of *jagung bose* (10%). The wavenumber of 1748 cm$^{-1}$ with the intensity of 62% was found in white corn, but it was not detected in *jagung bose*. Data in Table 1 show that the fat content of whole corn was higher than *jagung bose*. The FTIR spectra corresponded well to the quantity of fat in whole corn and *jagung bose*.

The absorbance at 1047 cm$^{-1}$ is sensitive to the crystalline amount of starch, and the absorbance at 1022 cm$^{-1}$ reflects the amorphous starch [36]. The peaks near 1022 cm$^{-1}$ were present for whole corn (1019 cm$^{-1}$) and *jagung bose* (1021 cm$^{-1}$) with 10 and 17%, respectively. However, the bands near 1047 cm$^{-1}$ were not found in both samples. Compared to whole corn, *jagung bose* revealed more crystalline starch. Pericarp removal slightly increased the quantity of starch, which means the amorphous region of starch also increased. There is no complicated process to convert whole corn into *jagung bose* that might affect the crystallinity of starch.

## Crystallinity

XRD was used to study the crystallinity of whole corn and *jagung bose*. According to K[illegible] et al. [37], the distinct peaks demonstrate the starch granule crystalline nature. The peaks at 19–21° (2θ angle) indicated a crystalline structure of the amylose–lipid complex in the starch granule. Figure 10 shows the sharp peaks between 15–25° (2θ angle) in whole corn and *jagung bose*. Both samples had a sharp peak at 15, 17, 18, and 23° (2θ angle), which was A-type crystalline starch [38]. The XRD patterns of whole corn and *jagung bose* were similar to those reported by Wang et al. [38] for native corn. Corn starch had A-type X-ray diffraction pattern [37], with peaks at 15°, 17° and 23° (2θ angle) [39]. The A pattern results from a close-packing arrangement with a water molecule between each double helix chain. The more open structures have the strongest peaks around 15°, 17°, and 23° (2θ angle). The peak at 18° (2θ angle) is a feature of the A-type pattern [40].

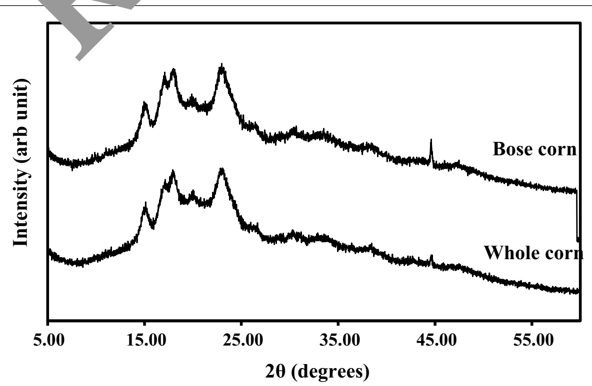


**Fig. 10** XRD spectra of whole corn and *jagung bose*

A strong peak of 45° was found in both samples, but the intensity was higher in *jagung bose* than in whole corn. Commonly, corn starch's peak at 45° (2θ angle) was not found [36, 41–43]. This peak represented higher crystallinity of *jagung bose* than that of whole corn. The higher starch and amylose of *jagung bose* than whole corn might contribute to this feature. Preparation of *jagung bose* from whole corn involved simple processing, which only pericarp removal and pounding with some added water. This process did not change the crystallinity of starch. The crystalline nature of *jagung bose* might be attributed to prolonged storage in the *rumah bulat* and slowly drying due to an arid environment and heating from the furnace during storage.

## Starch granule morphology

The majority of the starch granules are polygonal, with others being oval (Fig. 11). Whole corn revealed more complexity/aggregation of polygonal granules than *jagung bose*. Pounding to release pericarp from the kernels by adding water gradually in *jagung bose* preparation caused a variation in the surface of the starch granules. *Jagung bose* showed a smoother starch granule surface than that of whole corn. Starch granules absorbed water during pounding. Limited water availability and no heating treatment made the changes not severe that only a slight change in starch granule surface. Particles other than starch granules adhered more in *jagung bose* than whole corn. Water addition during pounding made a water bridge between a particle that made some other particles adhere to starch granules in *jagung bose*.

The morphology of starch granules of whole corn and *jagung bose* was in accordance with another report. The corn starch granules were polygonal, with a high degree of regularity and a smooth surface [42]. Perera et al. [41] reported that starch granules from normal and waxy corn displayed angular or spherical shapes. During the preparation of *jagung bose* from whole corn, the integrity of starch granules was still maintained. According to Guo et al. [42], the crystalline structure determined the starch granules' integrity. The destruction of the crystalline region made the starch particles' macrostructure change significantly. Preparation of *jagung bose* did not change

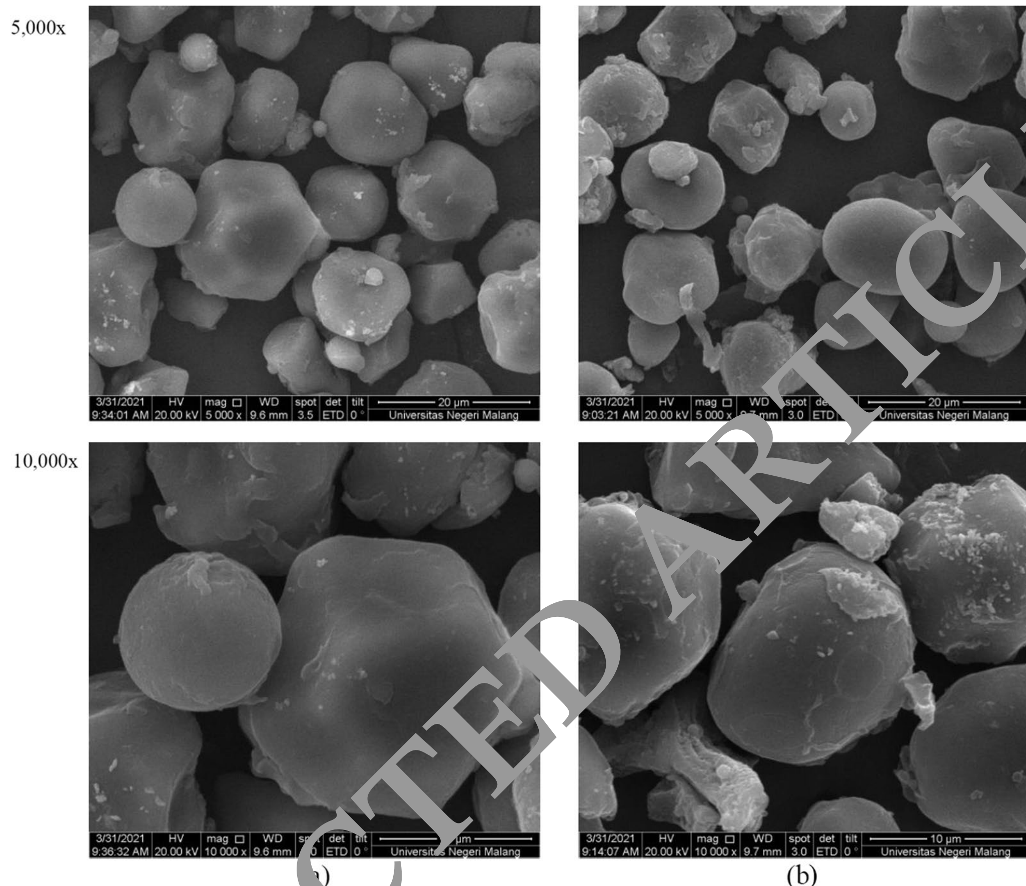


**Fig. 11** Morphology of whole corn (**a**) and *jagung bose* (**b**) starch granule morphology with 5,000 and 10,000 magnifications

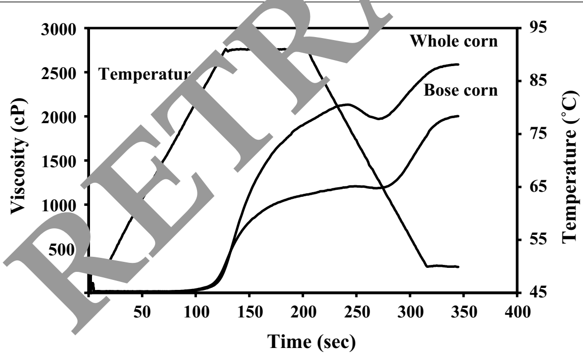


**Fig. 12** Amylogram of whole corn and *jagung bose*

**Table 3** Whole corn and *jagung bose* pasting properties

| Pasting properties | Whole corn | *Jagung bose* |
|---|---|---|
| Gelatinization temperature (°C)* | 88.00 ± 0.55 | 73.00 ± 0.34 |
| Pasting temperature (°C) | 74.95 ± 0.65 | 73.90 ± 0.71 |
| Peak viscosity (RVU)* | 1864 ± 11 | 1092 ± 13 |
| Peak time (s) | 2587 ± 19 | 2587 ± 20 |
| Breakdown viscosity (RVU)* | 10.00 ± 0.92 | 2.00 ± 0.48 |
| Final viscosity (RVU)* | 2587 ± 21 | 2002 ± 29 |
| Setback viscosity (RVU)* | 713 ± 9 | 908 ± 12 |

*Statistically different between whole corn and *jagung bose*

the crystalline structure severely; even the crystallinity increased, as indicated by XRD analysis.

## Pasting properties

The pasting profile and viscosity of whole corn and *jagung bose* are shown in Fig. 12 and Table 3. In general, the viscosity of whole corn was higher than that of *jagung bose*. The gelatinization temperature of whole corn was 80 °C; meanwhile, *jagung bose* had a gelatinization temperature of 78 °C. The high gelatinization temperature of whole corn and *jagung bose* was an indicator of the long cooking time of *jagung bose*. The high gelatinization temperature of whole corn might relate to high amylose content and crystallinity. Water was difficult to penetrate the crystalline structure of starch; thus, it required sufficient thermal energy and time for water absorption.

RETRACTED ARTICLE

RETRACTED ARTICLE

Long storage time and slow drying in *the rumah bulat* made the crystalline structure of starch. This corn still contained pericarp that is rich in fiber. Fiber hindered the gelatinization of starch due to water absorption competition, and fiber was easier to absorb water than starch [44]. The lower gelatinization temperature of *jagung bose* was due to pericarp removal during preparation. Pounding by adding some water also contributed to lower gelatinization temperature. Pounding broke down the kernel structure, thus increasing the surface area to absorb. During pounding, initial water absorption made the starch granules easier to swell and absorb more water during pasting and lowered the gelatinization temperature.

The pasting temperature of whole corn was higher than that of *jagung bose*. Whole corn was more difficult to increase viscosity due to the hindrance of fiber in the pericarp. Removing pericarp and pounding by adding water enhances starch granules' ability to absorb water, thus lowering the pasting temperature. However, the peak time of both samples was similar, indicating no different time to achieve the highest viscosity during pasting. Although some water was added during *jagung bose* preparation and eased the starch to absorb water to increase the viscosity, the fiber in the pericarp of whole corn assisted the in binding water. Therefore, the peak time of both samples was similar.

Data in Table 3 show that the peak, final, and breakdown viscosity of whole corn was higher than those of *jagung bose*; meanwhile, the setback viscosity was lower. The fiber in the pericarp contributed a higher peak viscosity of whole corn than that of *jagung bose*. Fiber could bind water and increase the viscosity of the food system. Removal of pericarp-containing fiber reduced the peak viscosity dramatically from 1864 to 1092 RVU. Fiber can maintain the absorbed water; meanwhile, starch chains, mainly amylose, were easier to release water molecules. Therefore, the final viscosity of *jagung bose* was lower than that of whole corn. *Jagung bose* tended to retrograde more quickly than whole corn, and water bound to fiber hindered the starch chains from bonding with each other in starch retrogradation.

*Jagung bose* maintained high viscosity during cooling; thus, it revealed low breakdown viscosity. Starch interchains bond occurred quickly and maintained high viscosity during cooking. The breakdown viscosity of whole corn was higher than that of *jagung bose*. The viscosity reduction in both samples was not sharp, indicating that both corn starches could maintain viscosity during temperature drops. After cooling at 50 °C, the final viscosity of whole corn was higher than that of *jagung bose.* Setback viscosity of *jagung bose* was higher compared to that of whole corn. *Jagung bose* had more pronounced retrogradation. More fiber in whole corn contributed to retaining water and preventing starch chains' retrogradation. High viscosity during cooling was an indicator of *jagung bose* hard texture. It was also an indicator that *jagung bose* was hard to cook and required a long cooking time.

## Conclusion

*Jagung bose* is a unique corn-based staple food with a constraint of long cooking time, which is made from *Pena muti' fatu* variety with high amylose, crystallinity, and A-type starch crystal structure. *Jagung bose* also revealed high crystallinity and A-type starch crystal structure. Long-time storage by hanging on the roof of *the rumah bulat* above the furnace for daily cooking resulted in high crystallinity that was scientifically proved from XRD data. Preparation of *jagung bose* from whole corn involved pericarp removal and pounding by adding some water. This process was simple but made some changes in corn characteristics. Traditionally, the native people of East Nusa Tenggara remove the pericarp in *jagung bose* preparation. This study proves the aims of preparing jagung bose, such as removing pericarp and water addition during pounding to soften the texture. Whole corn had more protein, fat, amylopectin, fiber, and ash but lower starch and amylose content. Starch granules of whole corn and *jagung bose* were the majority of polygonal shapes with a smooth surface. *Jagung bose* adhered to other particles more than whole corn. Pericarp removal and pounding by adding some water resulted in different pasting properties. The peak, final, and breakdown viscosity, pasting, and gelatinization temperatures of whole corn were higher than those of *jagung bose*; meanwhile, the setback viscosity of *jagung bose* was lower. The higher peak viscosity of whole corn than that of *jagung bose* was contributed by the fiber in the pericarp. High gelatinization temperature and crystallinity of *jagung bose* resulted in a long cooking time.

The limitation of this research is that the observations and interviews were conducted limitedly in unstructured and narrative manners. Further studies are needed to explore further the history of *jagung bose* and its processing methods. Preservation of this ethnic food is urgently needed to prevent shifting in the consumption of *jagung bose* as a staple food to others. One way is to develop technology to shorten the cooking time while maintaining the uniqueness and acceptance of this ethnic food. The government is suggested to have a role in campaigning the importance and pride of consuming *jagung bose* as a staple food.

#### Abbreviations

*Alu* or *hanu*: Pestle, a round and long pounder from hardwood; *Atoni Pah Meto*: People in the South-Central Timor district at Timor Island, East Nusa Tenggara;

*Bose*: Pounded; *Daging Se'i*: Traditional roasted meat; East Nusa Tenggara: A province in Indonesia that is islands; *Esu*: One of the main tools used by the *Atoni Pah Meto* community functions as a container for pounding rice or corn. Currently, it is made from hard tree trunks.; *Fatu*: Stone; *Fatu esu*: Stone mortar; *Jagung*: Corn; *Jagung bose*: Corn pounded with a mortar to remove the outer husk and dirt, and has no pericarp (husk); *Kacang nasi merah*: Ricebean, *Vigna umbellata*; *Kacang turis hitam*: Pigeon pea, *Cajanus cajan*; *Katemak corn*: A menu of Timorese that consisted of five main ingredients: corn, pumpkin, ricebeans, peanuts, and pumpkin leaves; *Lesung*: Mortar; *Muti'*: White; *Pena'*: Corn; *Pena' muti'*: White corn; *Pena' muti' fatu*: A local white corn variety from East Nusa Tenggara with a hard texture like a stone; *Pena' pasu*: Corn that still has the pericarp; *Rumah bulat*: Roundhouse, a traditional house of East Nusa Tenggara, with the round rooftop; *Salome*: A typical tradition of corn farmers, an acronym for "one hole filled with crowds; *Suap raja* tradition: People prepared food for the ruling kings; *Timor Island*: An island at East Nusa Tenggara; *Timorese*: The native people of Timor Island in East Nusa Tenggara province.

**Acknowledgements**
The authors are very grateful to the Ministry of Education, Culture, Research and Technology, Republic of Indonesia, for funding this study through Doctoral Dissertation Research (*Penelitian Disertasi Doktor*) at the year 2021.

**Author contributions**
The first author contributed to the design of the study, data collection, analysis, interpretation, manuscript preparation, and revision. The second author was responsible for study design, data acquisition, analysis, interpretation, supervising, manuscript preparation, and revision. The third and fourth authors had the role of supervision.

**Funding**
There is no funding resource that could be reported for this publication.

**Availability of data and materials**
All data are presented in this main paper.

## Declarations

**Competing interests**
All authors declare there are no competing interests regarding this publication.

**Author details**
[1]Doctoral Program of Food Science, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia. [2]Department of Food Science and Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia.

Received: 24 January 2022 Accepted: 19 June 2022
Published online: 28 June 2022

RETRACTED ARTICLE

**References**
1. Shi F, Dedeoğlu BB, Okumus B. Will diners be enticed to be travelers? The role of ethnic food consumption and its antecedents. J Destin Mark Manag. 2022;23:100685. https://doi.org/10.1016/j.jdmm.2021.100685.
2. Kwon DY. Why ethnic foods? J Ethn Foods. 2015;2:91. https://doi.org/10.1016/j.jef.2015.08.006.
3. Yulita KS, Naiola BP. Keragaman genetik beberapa aksesi jagung dari nusa tenggara timur berdasarkan profil *Inter Short Sequence Repeat (ISSR)*. J Biologi Indones. 2013;9(2):255–63.
4. Miller G. Indonesia Timur Tempo Doeloe 1544–1992. Konunitas Banbu, Jakarta; 2012.
5. Kasijanto, Sihotang VBL. Ladang Jagung di Lahan Kering: Peradaban Agraris Nusa Tenggra Timur. Direktorat Sejarah, Direktorat Jenderal Kebudayaan, Kemeterian Pendidikan dan Kebudayaan, Jakarta; 2018.
6. Liubana MMJ. Nenohai I Unsur kearifan lokal masyarakat Atoni Pah Meto dalam legenda Oepunu. Jurnal Onoma: Pendidikan Bahasa dan Sastra. 2021;7(2):449–61.
7. Aghababaei A, Maftoonazad N, Elhamirad A, Badii F. Accelerated ageing of wheat grains: part II-influence on thermal characteristics of wheat starch and FTIR spectroscopy of gluten. J Cereal Sci. 2017;2017(77):157–65. https://doi.org/10.1016/j.jcs.2017.08.010.
8. Nawaz MA, Fukai S, Prakash S, Bhandari B. Effects of three types of modified atmospheric packaging on the physicochemical properties of selected glutinous rice. J Stored Prod Res. 2018;76:85–95. https://doi.org/10.1016/j.jspr.2018.01.005.
9. AOAC International. Official Methods of Analysis of AOAC International, 18th Ed. Methods 985.29. AOAC International: Gaithersburg; 2007
10. Ramdath DD, Lu ZH, Maharaj PL, Winberg J, Brummer Y, Hawke A. Proximate analysis and nutritional evaluation of twenty Canadian lentils by principal component and cluster analyses. Foods. 2020;9(2):175. https://doi.org/10.3390/foods9020175.
11. Naves MMV, de Castro MVL, de Mendonça AL, Santos GG, Silva MS. Corn germ with pericarp in relation to whole corn: nutrient contents, food and protein efficiency, and protein digestibility-corrected amino acid score. Ciênc Tecnol Aliment Campinas. 2011;31(1):264–9.
12. Chateigner-Boutin AL, Alvarado JJOOC, Bouchet B, Durand S, Verhertbruggen Y, Barrière Y, Saulnier L. Developing pericarp of maize: a model to study arabinoxylan synthesis and feruloylation. Front Plant Sci. 2016;7:1476. https://doi.org/10.3389/fpls.2016.01476.
13. Khatun MHA, Wang L, Chen H. High solids all-inclusive polysaccharide hydrolysis of steam-exploded corn pericarp by periodic peristalsis. Carbohydr Polym. 2020;246:116483. https://doi.org/10.1016/j.carbpol.2020.116648.
14. Alvarez-Jubete L, Arendt EK, Gallagher E. Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. Int J Food Sci Nutr. 2009;60(Suppl 4):240–57.
15. Xin H, Sun F, Sun K, Fu Q, Li Y, Zhang Y, Rahman SU, Khand NA. Batch-to-batch variation in carbohydrates molecular structures, nutritive value and biodegradation characteristics in corn coproducts. Anim Feed Sci Technol. 2020;263:114458. https://doi.org/10.1016/j.anifeedsci.2020.114458.
16. Somavat P, Liu W, Singh V. Wet milling characteristics of corn mutants usingmodified processes and improving starch yields from high amylose corn. Food Bioprod Process. 2021;126:104–12. https://doi.org/10.1016/j.fbp.2020.12.015.
17. Han KT, Kim HR, Moon TW, Choi SJ. Isothermal and temperature-cycling retrogradation of high-amylose corn starch: Impact of sonication on its structural and retrogradation properties. Ultrason Sonochem. 2021;76:105650. https://doi.org/10.1016/j.ultsonch.2021.105650.
18. Donmez D, Pinho L, Patel B, Desam P, Campanella OH. Characterization of starch–water interactions and their effects on two key functional properties: starch gelatinization and retrogradation. Curr Opin Food Sci. 2021;39:103–9. https://doi.org/10.1016/j.cofs.2020.12.018.
19. Li C, Hamaker BR. Effects of different storage temperatures on the intra- and intermolecular retrogradation and digestibility of sago starch. Int J Biol Macromol. 2021;182:65–71. https://doi.org/10.1016/j.ijbiomac.2021.03.195.
20. Li LL, Ming B, Xue J, Gao S, Wang K, Xie R, Hou P, Li S. Difference in corn kernel moisture content between pre- and post-harvest. J Integr Agric. 2021;20(7):1775–82. https://doi.org/10.1016/S2095-3119(20)63245-2.
21. Zhang Y, Silcock P, Jones JR, Eyres GT. Changes in wood smoke volatile composition by manipulating the smoke generation conditions. J Anal Appl Pyrolysis. 2020;148:104769. https://doi.org/10.1016/j.jaap.2019.104769.
22. Soares JM, da Silva PF, Puton BMS, Brustolin AP, Cansian RL, Dallago RM, Valduga E. Antimicrobial and antioxidant activity of liquid smoke and its potential application to bacon. Innov Food Sci Emerg Technol. 2016;28(A):189–197. https://doi.org/10.1016/j.ifset.2016.10.007.
23. Paraginski RT, de Souza NL, Alves GH, Ziegler V, de Oliveira M, Elias MC. Sensory and nutritional evaluation of popcorn kernels with yellow, white and red pericarps expanded in different ways. J Cereal Sci. 2016;69:383–91. https://doi.org/10.1016/j.jcs.2016.05.0.
24. Zhang R, Ma S, Li L, Zhang M, Tian S, Wang D, Liu K, Liu H, Zhu W, Wang X. Comprehensive utilization of corn starch processing by-products: a review. Grain Oil Sci Technol. 2021;4(3):89–107. https://doi.org/10.1016/j.gaost.2021.08.003.
25. Jaworski NW, Lærke HN, Knudsen KEB, Stein HH. Carbohydrate composition and in vitro digestibility of dry matter and non starch

polysaccharides in corn, sorghum, and wheat and coproducts from these grains. J Anim Sci. 2015;93:1103–13. https://doi.org/10.2527/jas2014-8147.

26. Santiago-Ramos D, Figueroa-Cardenas JD, Mariscal-Moreno RM, Escalante-Aburto, Ponce-García N, Veles-Medina JJ. Physical and chemical changes undergon Ae by pericarp and endosperm during corn nixtamalization—a review. J Cereal Sci. 2018;81:108–117. https://doi.org/10.1016/j.jcs.2018.04.003.
27. Xin H, Khan NA, Sua K, Sun F, Su R, Fu Q, Li Y, Zhang Y, Hu G. Batch-to-batch variation in protein molecular structures, nutritive value and ruminal metabolism in corn coproducts. Anim Feed Sci Technol. 2020;263: 114428. https://doi.org/10.1016/j.anifeedsci.2020.114428.
28. Kato FH, Carvalho MEA, Gaziola SA, Piotto FA, Azevedo RA. Lysine metabolism and amino acid profile in maize grains from plants subjected to cadmium exposure. Sci Agric. 2020;77(1):1201. https://doi.org/10.1590/1678-992X-2018-0095.
29. Marrufo-Díaz ML, Vázquez-Carrillo MG, Santiago-Ramos D, Ybarra-Moncada MC, Mejía-Andrade H. Physicochemical and sensory properties of 'corn on the cob' (elotes) from quality protein maize (QPM) hybrids as influenced by harvest stage and cold storage time. J Cereal Sci. 2021;2021(102):103348. https://doi.org/10.1016/j.jcs.2021.103348.
30. Cueto M, Farroni A, Rodríguez SD, Schoenlechner R, Schleining G, Buera MP. Assessing changes in enriched maize flour formulations after extrusion by means of FTIR, XRD, and chemometric analysis. Food Bioprocess Technol. 2018;11:1586–95. https://doi.org/10.1007/s11947-018-2113-6.
31. Balan V, Mihai CT, Cojocaru FD, Uritu CM, Dodi G, Botezat D, Gardikiotis I. Vibrational spectroscopy fingerprinting in medicine: from molecular to clinical practice. Materials. 2019;12(18):2884. https://doi.org/10.3390/ma12182884.
32. Capron I, Robert P, Colonna P, Brogly M, Planchot V. Starch in rubbery and glassy states by FTIR spectroscopy. Carbohydr Polym. 2007;68(2):249–59. https://doi.org/10.1016/j.carbpol.2006.12.015.
33. Kong J, Yu S. Fourier Transform infrared spectroscopic analysis of protein secondary structures. Acta Biochim Biophys Sin. 2017;39(8):549–59. https://doi.org/10.1111/j.1745-7270.2007.00320.x.
34. Sadat A, Joye IJ. Peak fitting applied to fourier transform infrared and raman spectroscopic analysis of proteins. Appl Sci. 2020;10:5918. https://doi.org/10.3390/app10175918.
35. Derenne A, Vandersleyen O, Goormaghtigh E. Lipid quantification method using FTIR spectroscopy applied on cancer cell extracts. Biochim Biophys Acta. 2014;1841:1200–9. https://doi.org/10.1016/j.bbalip.2013.10.010.
36. Li X, Wang Y, Mu S, Ji X, Zeng C, Yang D, Dai L, Duan C, Li D. Structure, retrogradation and digestibility of waxy corn starch modified by a GtfC enzyme from *Geobacillus* sp. 12AMOR1. Food Biosci. 2022;46:101527. https://doi.org/10.1016/j.fbio.2021.101527.
37. Kibar EAA, Gönenç I, Us F. Gelatinization of waxy, normal and high amylose corn starches. GIDA. 2010;35(4):237–44.
38. Wang B, Dong Y, Fang Y, Gao W, Kang X, Liu P, Yan S, Cui B, El-Aty AMA. Effects of different moisture contents on the structure and properties of corn starch during extrusion. Food Chem. 2022;368:130804. https://doi.org/10.1016/j.foodchem.2021.130804.
39. Shaikh F, Ali TM, Mustafa G, Hasnain A. Structural, functional and digestibility characteristics of sorghum and corn starch extrudates (RS3) as affected by cold storage time. Int J Biol Macromol. 2020;2020(164):3048–54. https://doi.org/10.1016/j.ijbiomac.2020.08.105.
40. Manek RV, Builders PF, Kolling WM, Emeje M, Ku OO. Physicochemical and binder properties of starch obtained from *Cyperus esculentus*. AAPS Pharm Sci Tech. 2012. https://doi.org/10.1208/s12249-012-9761-z.
41. Perera C, Lu Z, Sell J, Jane J. Comparison of physicochemical properties and structures of sugary-2 cornstarch with normal and waxy cultivars. Cereal Chem. 2001;78(3):249–56.
42. Guo J, Wang J, Zheng G, Jiang X. Optimization of the removal of reactive golden yellow SNE dye by cross-linked cationic starch and its adsorption properties. J Eng Fibers Fabr. 2019;14:1–13. https://doi.org/10.1177/1558925019865260.
43. Li D, Yang N, Wu Z, Xu E, Zhou Y, Cui B, Han Y, Tao Y. Effects of connection mode on acid hydrolysis of corn starch during induced electric field treatment. Int J Biol Macromol. 2022;200:370–7. https://doi.org/10.1016/j.ijbiomac.2021.12.177.
44. Wu N, Qiao CC, Tian XH, Tan B, Fang Y. Retrogradation inhibition of rice starch with dietary fiber from extruded and unextruded rice bran. Food Hydrocoll. 2021;113:106488. https://doi.org/10.1016/j.foodhyd.2020.106488.


RETRACTED ARTICLE

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.


Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

**At BMC, research is always in progress.**

**Learn more** biomedcentral.com/submissions

BMC