

ISSN 2709-3409 (Online)

JOURNAL OF TERTIARY AND INDUSTRIAL
SCIENCES

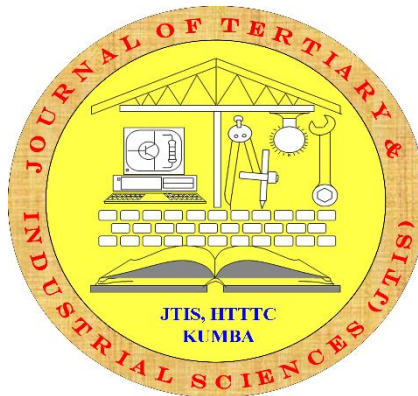
**Second Annual International Conference in HTTTC
Kumba**

6-7 May, 2026

Theme

**Entrepreneurship and Small Businesses: The Bedrock
for Development and Innovation**

A MULTIDISCIPLINARY JOURNAL OF THE HIGHER TECHNICAL TEACHERS'
TRAINING COLLEGE, KUMBA



CONFERENCE PAPERS

PUBLISHER:
**HIGHER TECHNICAL TEACHERS' TRAINING COLLEGE (HTTTC)
UNIVERSITY OF BUEA**

P.O Box: 249 Buea Road, Kumba

Tel: (+237) 33354691 - Fax: (+237) 33354692

Email: editor@jtis-htttcubuea.com

Website: <https://www.jtis-htttcubuea.com>

EDITORIAL BOARD

Supervision:

Professor Ngomo Horace Manga
University of Buea

Editor-in-Chief:

Prof. Akume Daniel Akume, University of Buea, Cameroon

Associate Editors:

Prof. Ebune B. Joseph, University of Buea, Cameroon
Prof. Defang Henry, University of Buea, Cameroon
Prof. Lissouck Daniel, University of Buea, Cameroon

Advisory Editors:

Prof. Tabi Johannes Atemnkeng, University of Buea, Cameroon
Prof. Leno Doris, University of Buea, Cameroon
Prof. Lyonga N. Agnes Ngale, University of Buea, Cameroon
Members of the Editorial Board:
Prof. Yamb Belle Emmanuel, University of Douala, Cameroon
Prof. Ambe Njoh Jonathan, University of South Florida, USA
Prof. John Akande, Bowen University, Nigeria
Prof. Talla Pierre Kisito, University of Dschang, Cameroon
Prof. Rosemary Shafack, University of Buea, Cameroon
Prof. Njimanted Godfrey Forgha, University of Bamenda, Cameroon
Prof. Nzalie Joseph, University of Buea, Cameroon
Prof. Mouange Ruben, IUT University of Ngaoundere, Cameroon
Prof. Boum Alexander, University of Buea, Cameroon
Prof. Patrick Wanyu Kongnyuy, University of Bamenda, Cameroon
Prof. Tchuen Ghyslain, IUT Badjoun, University of Dschang, Cameroon
Prof. Rose Frieri-Manyi Anjoh, University of Buea, Cameroon
Prof. Foadieng Emmanuel, University of Buea, Cameroon
Prof. Tchinda Rene, IUT Badjoun, University of Dschang, Cameroon
Prof. Tabi Pascal Tabot, University of Buea, Cameroon
Prof. Katte Valentine, University of Bamenda, Cameroon
Prof. Zinkeng Martina, University of Buea, Cameroon
Prof. Obama Belinga Christian Theophile, University of Ebolowa, Cameroon
Prof. Nkongho Anyi Joseph, University of Buea, Cameroon
Prof. Cordelia Givechek Kometa, University of Buea, Cameroon
Prof. Ngouateu Wouagfack Paiguy, University of Buea, Cameroon
Prof. Tchakoutio Alain, University of Buea, Cameroon
Prof. Morfaw Bertrand, University of Buea, Cameroon
Prof. Tamba Gaston, IUT University, Douala, Cameroon
Prof. Koumi Simon, ENS, Ebolowa, University of Yaounde I
Prof. Ajongakoh Raymond, University of Buea, Cameroon

Prof. Ntabe Eric, University of Buea, Cameroon
Prof. Kinfack Juetsa Aubin, University of Buea, Cameroon
Prof. Bahel Benjamin, University of Buea, Cameroon
Prof. Agbortoko Ayuk Nkem, University of Buea, Cameroon
Dr. Abanda Henry Fonbiyen, Oxford Brookes University, UK
Dr. Luis Alberto Torrez Cruz, University of Witwatersrand, South Africa
Dr. Negou Ernest, University of Buea, Cameroon
Dr. Aloyem Kaze Claude Vidal, University of Buea, Cameroon
Dr. Mfombep Priscilla Mebong, University of Buea, Cameroon
Dr. Asoba Gillian, University of Buea, Cameroon
Dr. Massa Ernest, University of Buea, Cameroon
Dr. Mouzong Pemi, University of Buea, Cameroon
Dr. Orock Fidelis Tanyi, University of Buea, Cameroon
Dr. Wanie Clarkson Mvo, University of Bamenda, Cameroon
Dr. Molombe Jeff Mbella, University of Buea, Cameroon
Dr. Emmanuel Tata Sunjo, University of Buea, Cameroon
Dr. Ndi Roland Akoh, University of Yaounde I, Cameroon
Dr. Nkenganyi Fonkem Marcellus, University of Buea, Cameroon
Dr. Hannah Kolle, University of Buea, Cameroon
Dr. Kamda Silapeux Aristide, University of Buea, Cameroon
Dr. Roland Ndah Njoh, University of Buea, Cameroon

Managing Editor:

Dr. Negou Ernest, University of Buea, Cameroon

CONTENTS

ECONOMICS AND MANAGEMENT SCIENCES

Jaff and Negou (2026) The contributions of microfinance institutions in the promotion of agribusinesses. Case of NTACCUL in Kumba Municipality1

Eyong and Njie (2026) Human Capital, Technological Catch-up, and Growth Divergence in Sub-Saharan Africa (1)17

Mbonteh (2026) Enterprise Education: A Strategy for the Survival of Startup SMES in the Southwest Restive Region of Cameroon40

GUIDANCE COUNSELLING

Elime and Kollé (2026) Counselling Based Entrepreneurial Interventions and Sustainable Small Business Development (SMS) in Kumba Municipality, South West Region, Cameroon54

HOME ECONOMICS

Asoba et al. (2026) The Effects of Local Preservation Methods on the Nutritional Content of Yellow Corn (Zea Mays) in Bamngam Village, Bui Division, Cameroon66

The Effects of Local Preservation Methods on the Nutritional Content of Yellow Corn (*Zea Mays*) in Bamngam Village, Bui Division, Cameroon

Ruth Berinyuy¹

Gillian Nkeudem Asoba¹

asobis2000@yahoo.com

Fidelis Sameh Ebong¹

Aristide Guillaume Silapeux Kamda¹

Metuge Samuel¹

Irene UleNgoleSumbele^{2*}

Sumbelei@yahoo.co.uk/sumbele.irene@ubuea.cm

¹Department of Social Economy and Family Management, Higher Technical Teachers' Training College, University of Buea, Kumba, Cameroon.

²Department of Zoology and Animal Physiology, University of Buea, Buea, Cameroon.

*Corresponding author

To cite: Berinyuy et al. (2026, June 10). The Effects of Local Preservation Methods on the Nutritional Content of Yellow Corn (*Zea Mays*) in Bamngam Village, Bui Division, Cameroon. Special Edition. The Journal of Tertiary and Industrial Sciences (JTIS), HTTTC Kumba. <https://doi.org/10.5281/zenodo.20574551>

Submission Date: 13/02/2026

Acceptance Date: 22/05/2026

Abstract

Corn is a staple food in the Bamngam village and other communities in Cameroon. It has been suggested that the type of post-harvest preservation methods of yellow corn affect its nutritional quality but no study has specifically investigated this claim in the Bamngam village. This study was carried out to identify the different local storage methods used for the preservation of yellow corn in Bamngam village in the North West Region of Cameroon and to determine the effect of each method on the nutritional quality of corn. Questionnaires were used to investigate the different storage techniques of corn used by farmers in this community. Corn samples stored under three different conditions were collected from a selected farmer and transported to the laboratory in ENSAI Ngaoundere for analysis. Results showed that 60% of corn in the village is stored in barns, 20% by husk hung outside and 20% stored as free grains in plastic containers (hermetic storage). The dry matter content (88.4 ± 0.56) and fibre content (10.16 ± 0.96) of corn samples from hermetic storage were significantly higher ($p < 0.05$) than in other storage methods while the water (11.55 ± 0.56) and protein content (7.16 ± 0.24) were significantly lower in corn from hermetic storage. The ash, lipid and sugar contents of the samples were not affected by the different storage techniques. Corn from the barn had significant ($p < 0.05$) higher iron content (4.34 ± 0.21) while corn samples from hermetic storage had significant ($p < 0.05$) higher phosphate content (683.83 ± 93.49). In addition, the zinc (6.80 ± 1.18) and calcium (120.61 ± 28.09) contents of the corn from the husk hanging outside and the barn were significantly higher than in other storage conditions. The magnesium content of the samples was not affected by these storage methods. The results also showed that corn stored in plastic containers had healthy non-moldy seed that were least damaged by insects. On the other hand, the seeds from barn and hung outside showed a decrease in quality as compared to those in sealed plastic containers. The microbial analysis showed that total coliform bacteria were of acceptable level in all the three samples, yeast and mold were present in the three samples in the not satisfactory level. Total aerobic mesophilic flora was found at the acceptable level for corn stored in plastic container and not satisfactory level for corn stored in barn and hung outside. The nutritional content of corn in Bamngam is affected by storing methods and corn stored in sealed plastic container should be adopted as storing method of corn.

Keywords: Corn, local storage, nutritional content, storage structure, Bamngam

1. Introduction

Corn also known as maize (*Zea mays* L.) is an important cereal that is ranked third in global production and consumption after wheat and rice (Asghar *et al.*, 2010). Globally, corn is known as queen of cereals because of its high genetic yield potential (Kumar *et al.*, 2013) and its wide adaptability to many agricultural zones. According to Harold (2015), corn is a major staple food crop grown in diverse agro-ecological zones and farming systems, and consumed by people with varying food preferences and socio-economic backgrounds in Sub-Saharan Africa (SSA). Out of 22 countries in the world where corn forms the highest percentage of calorie intake in the national diet, 16 are in Africa (Harold, 2015). A large quantity of corn is being harvested in the wet season with high moisture content making it vulnerable to damage by microorganisms and insects

The constraints of the corn sector are the postharvest storage. It is estimated that Africa suffers postharvest loss of 20% - 30% estimated at 4 billion dollars annually (Kodwo, 2015). In tropical and subtropical countries, a large proportion of the corn is harvested and stored under hot/humid conditions and most farmers lack equipment and knowledge on methods of drying corn (Rashad *et al.*, 2013). Inadequate infrastructure and lack of economic means are some of the major constraints of smallholder farmers to store corn after harvest (Niamketchi *et al.*, 2015). Due to this, most rural and small scale corn farmers embark on traditional storage structures and methods like living rooms, barns, cribs, baskets, polypropylene bags, sealed plastic containers, earthen ware and granaries. Crops generally kept in these inadequate conditions and structures are subject to spoilage by insects, rodents and fungi leading to high postharvest losses (Dejenea *et al.*, 2006). The lack of modern and suitable storage structures and technologies for grains often cause the farm smallholders to sell their produce immediately after harvest and at low prices (Kodwo, 2015).

Lack of proper storage of grains may affect their nutritional content and seed quality. According to Kodwo (2015), storage is done to maintain quality of harvested product not to improve it. To avoid the quality and quantity from declining, farmers use different preservation techniques during storage. Due to the potential hazardous effects on the environment and human health, there has been a shift from the use of synthetic chemical grain preservatives to local and natural methods (Akob and Ewete, 2010) to increase the shelf life of stored grains. It is therefore, necessary to evaluate the effect of these local preservation methods on the nutritional quality of cereals.

2. Literature Review

Overview on Corn

Corn also known as maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain. This crop originated in Mexico from where, it spreads to all over the world as a major food crop (Kalidas and Ma, 2011). According to Kumar *et al.*, 2013, its origins are believed to date back to at least 7000 years ago when it was grown in the form of a wild grass called *teosinte* in Central Mexico and recognizing its early potential as a major food

crop, over a time the *Mesoamerican* natives managed to improve the crop, by systematically selecting certain varieties for their desired traits. This process led to the gradual transformation of *teosinte* to its present-day form known as corn. Corn is the only food cereal crop that can be grown across different seasons and ecologies and it is a versatile crop having wider adaptability (Kumar *et al.*, 2013).

Classification of Corn

Cereals are members of the grass family Poaceae, also known as Gramineae and are cultivated for food. Botanically, corn is classified as follows:

Kingdom: Plantae

Division: Angiospermophyta

Class: Liliopsida

Order: Poales

Family: Poaceae

Genus: *Zea*

species: *mays*

Nutritional value of corn

The importance of cereal grains in human nutrition is widely recognized, as they provide substantial amounts of energy and protein to millions of people, especially in developing countries (FAO, 2011). Cereals are staple foods, providing a major source of carbohydrate, protein, B vitamins and minerals for the world's population and as well as containing a range of phytochemicals which may provide some of the health benefits seen among populations consuming diets based on plant foods (Brigid, 2004).

Corn kernel is an edible and nutritive part of the plant. Corn has both macronutrients and micronutrients which are needed by humans and livestock.

Methods of drying of corn

Drying is perhaps the oldest, most common and most diverse of chemical engineering unit operations in the preservation of agricultural food materials or product (Gumus and Ketebe, 2013). The drying operation reduces the moisture content of corn to a condition favourable for safe storage without deteriorations. The most significance reason for the popularity of dried products is that in dehydrated foods, microorganisms practically do not grow due to the presence of a minimum amount of water and thus they are immune to enzymatic reactions that could provoke alterations or spoilage in the food (Gumus and Ketebe, 2013). Corn is often harvested at a moisture content that is too high for safe storage. According to Sylvanus *et al.* (2015), in many countries, corn is harvested with quite a high moisture content, which can vary between 25% and 36% (wet-basis) or even higher and to preserve their quality after harvesting, corn grains are usually dried. With such a high moisture content at harvest, the corn will deteriorate very fast because its presence conditions favours the activities of spoilage microorganisms and other pest. According to Ray *et al.* (2013), drying is the most common post-harvest process performed for the long-term preservation

of grain. Corn drying is the process of reducing grain moisture to reach a safe moisture levels for long term storage.

Natural air drying of corn (sun drying)

The traditional methods used by farmers for drying corn rely on natural air movement to reduce moisture content to a safe level for storage. Sun drying of corn kernel is the drying method in the tropical developing countries. Natural drying may be divided into three main methods:

i. Drying in the field before harvesting.

ii Drying in shallow layers and exposing to sun and wind on a surface that prevents moisture from the ground from reaching the produce.

iii Drying in, or on, a structure that has open sides to permit air movement through the mass
In Cameroon for examples some farmers cultivate corn twice a year. The rainy season harvest can be harvested when the moisture content is still higher unlike the dry season harvest where the corn can be left in the field to dry properly before harvest and to continue drying at home. According to Zubaida *et al.* (2015), corn can be sun dried although during drying, crops get sensitive to insect infestation, rodent or birds' attack, mold damage and a threshed corn drying by spreading on sheets or tray is a common phenomenon but has a risk of soil or stone contamination. In the North West of Cameroon, ears of the corn are hung outside of the building and left to be dried. The corn could be hung with husk or dehusk and drying continues naturally. However, the corn is exposed to pests and other contaminants.

Artificial drying of corn

This method of corn drying is common in the developed countries and with farmers with large quantity of crop yield. If the air humidity is too high to allow grain to be dried adequately by natural means and storage methods do not facilitate further drying, it is necessary to dry the produce using forced air or heat, or a combination of both. According to Langsi *et al.* (2017), drying of corn is usually done indoors in barns with the use of smoke from hearth fires. According to Kodwo (2015), the heat and smoke from fire help in drying and scaring off insect pests from the crop, keeping the grain intact and safe for future planting.

However, drying grain quickly and effectively after harvest and before storage retains maximum quality, to attain a moisture content sufficiently low to minimize infestation by insect and microorganism and to prevent germination (FAO, 2011).

Corn storage

Storage is the phase of the post-harvest system during which agricultural products are kept in such a way as to maintain their quality and prevent them from deterioration for a specific period beyond their normal shelf-life (FAO, 2017). The prevention of deterioration of the quality of the grain is achieved through control of moisture and air movement, by preventing infestation of microorganisms and attacks of insects and rodents. Globally, over 2.58 billion tons of cereal grains such as corn, wheat, rice (FAO, 2017) is produced annually, and these cereal grains are stored for the purpose of food security and sustainability (Jacek *et al.*, 2008). According to Olakojo and Akinlosotu (2004), insect pests are one of the major organisms that are responsible for decline in quantity, quality and germination potential of corn seeds in storage. Adequate and effective storage of corn grains is therefore a major task to farmers to enhance corn quality and quantity during storage to reduce the huge economic

loss. Bad storage practices or facilities may create a conducive environment for mold and pest proliferation that are responsible for significant losses at household level. Therefore, all storage systems must be designed to adequately protect and preserve the quality of the corn during storage time.



Figure 1: Husk hanging of corn outside under shade (open air storage on ceiling)



Figure 1: Corn stored in bags

Another storage facility is placing shelled corn in plastic containers (hermetic storage structure). According to Costa (2014), hermetic storage therefore involves storage of commodities in an airtight and watertight or low permeability environment, that provides negligible or no gas exchange between the hermetic environment and external environment. This method has the advantage of keeping away pest, rodents and birds from the corn thus having a product which is pathogen-free and of good quality. However, it cannot be used by farmers with high yield.



Figure 2: Hermetic storage of grains in plastic containers

Modern storage facilities or structures

Modern storage structures have higher storage capacity and long-term storage of corn grains than traditional storage structures. These modern storage structures include: Improved crib, Ware house, Silo/ Bin, and Hermetic and nitrogen storage systems. Kevin (2019), indicated that a major motivation for the use of improved storage facilities is the protection of stored agricultural products against insect attack and the need to reduce post-harvest losses in grains is compelling most agriculturists to invest in safer storage facilities. Silos are an efficient method of storing grain. There are different types of silos of various sizes for storing grain in bulk. Silos are either constructed from concrete, bricks or sheet metal bolted together. Bulk grain takes less space and can be handled mechanically hence reducing bagging and handling costs.



Figure 3: Corn silo in IRAD Bambui

3. Research Methodology

Study Area

The study was conducted in the Bamngam village located in Kimbo Sub Division in the Bui Division, North West Region of Cameroon. Bui Division lies within the Latitude 6° 15'N and Longitude 10° 45'E. The division occupies a surface area of 2,297 km² with a population of 322,877 thousand as of 2005 census.

The topography of Bui is characterized by abrupt escarpments, towering mountain peaks, deep valleys, broad alluvial plains that greatly influence the climate of neighbouring communities. Just like the other parts of Cameroon, Bui experience two distinct seasons: Longer rainy season usually between late March to early November and a shorter dry season usually between mid-November to late March recording an annual average rainfall of about 2400 mm with an average temperature of 23°C, ranging between 15-32°C.

Farming which is the main activity of the people of Bui involves local farming practices like shifting cultivation, bush fallowing, terracing and dry farming systems. Traditional agricultural systems predominate with primitive farming practices and poor management. Agriculture is still dominated with low use of fertilizers and high human labour characterized by the use of rudimentary tools and techniques like hoes, cutlasses and spades manual weeding, hoeing and harvesting. A variety of crops including vegetables are cultivated in Bui Division such as corn, Irish potatoes, cassava tomatoes, rice, yams, huckleberry, onion, and carrots are mostly done in small parcel of lands that is subsistence with low yields.

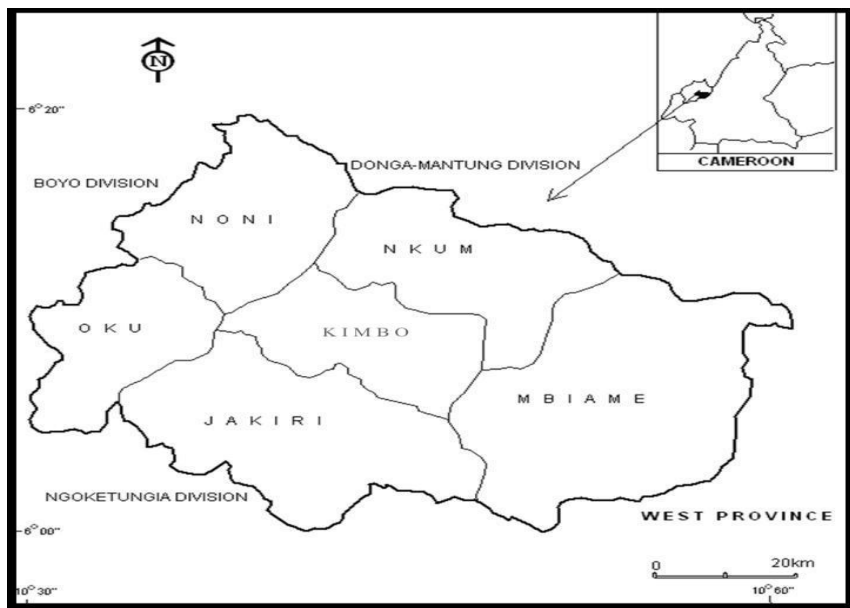


Figure 4: Map showing division of the study area

Research design, study population and sampling technique

This was a descriptive study involving local farmers in Bamngam village that cultivate maize and adopt various local methods of storing the corn. The knowledge of the species of corn cultivated in Bamngam and the different storage methods were obtained from farmers using a well written questionnaire. The questionnaire was written in English language and translated into “pidgin English and the local Lamnso dialect” for those that could not comprehend English language. The Farmers were selected by convenience and their responses recorded.

Collection of corn samples

After identifying the different storing methods in Bamngam, a farmer that cultivated the yellow corn species on large scale and had accepted of storing the corn using the different storing techniques identified in the community was selected by convenience. Corn samples from the different storage structures harvested from the same farm were collected and put in dry labelled plastic containers void of moisture.

Processing of corn samples

Collected corn samples from the different storing methods were sealed and transported in labeled dry plastic containers void of moisture and transported to the ENSAI laboratory in Ngoundere for analysis. Proximate analysis involved the determination of moisture content (%), ash (%), crude protein (%), crude fat (%), crude fibre (%) and carbohydrate (%). Microbial load analysis was also performed and included total mesophilic flora, total coliform bacteria, yeast and mold, clostridium sulfite-reducing and *Salmonella*. Other parameters considered in the analysis were the physiological, pathological and morphological properties of the corn like viability, seeds sustained mechanical damage, germinated seeds, malformed seeds, seed with abnormal colouring, seeds damaged by insects, moldy, rancid or rotten seeds, animal impurities and dead insects, other organic and inorganic materials and weight of 100 seeds.

Proximal determination of yellow corn composition

Water and Dry Matter Content

The dry matter or dry residue represents all the substances which do not volatilize under the drying conditions defined by the method used. The determination of the dry matter was carried out according to the AFNOR method of 1982. A mass (m) of the corn sample was introduced into a porcelain crucible whose empty mass (m_0) has been noted. The mass of the corn sample plus the crucible mass (m_1) was recorded and the assembly dried in an oven at 105°C for 24 hours until a constant mass was obtained. After drying, the crucible was removed from the oven, then cooled in a desiccators and weighed (m_2). The total dry residue or dry matter (DM) was expressed in percentage using the formula:

$$\% \text{ DM} = [(m_2 - m_0) / (m_1 - m_0)] \times 100$$

M_0 : the mass in grams of the empty capsule (crucibles);

M_1 : mass in grams of the crucible containing the corn sample before baking;

M_2 : mass in grams of the crucible containing the sample after baking;

DM: Dry matter

Three replicates per corn sample from a each storing method were performed and the average recorded.

The water and volatile matter content noted H is deduced from the dry matter content by the formula

$$\% \text{ H} = 100 - \text{DM}$$

Total Ash Content (Total Minerals)

The total ash was quantified by the method described in AFNOR, 1981 where the corn samples were completely incinerated until white ash was obtained in a muffle furnace set

at 550°C. For this, the porcelain crucibles containing the samples obtained from the 105 ±2 °C(m₂) were placed in the oven. After incineration for 24 hours, the crucibles were removed from the furnace using the tongs, then cooled in the atmosphere of a desiccator and weighed (M₃).

The ash content per 100g of DM was calculated using the formula:

$$\text{Total ash (\%)} = \frac{m_3 - m_0}{m_2 - m_0} \times 100$$

The test was performed in three replicates for each type of stored corn sample and the average recorded.

Extraction and Determination of total sugar content

To extract the sugars, 0.2g of the powdered corn sample were added to 5ml of 6N sulfuric acid and introduced into a test tube. The mixture was boiled at 100°C for 45 minutes, then cooled to room temperature. About 10mL of 70% ethanol plus 1mL of zinc acetate (2g / 100mL) and 1mL of potassium ferrocyanide (10.6g / 100mL) were then added. The mixture obtained was filtered into a 50mL flask and the volume of the filtrate made up to 50mL using distilled water.

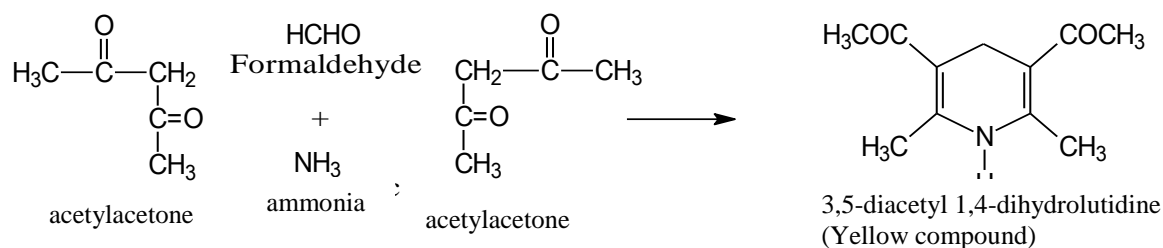
The determination of the total extracted sugars was measured according to the (DNS) method described by Fischer and Stein, (1961). In an alkaline and hot medium, DNS reacts with the extracted sugars and changes from its yellow oxidized form to its orange reduced form with maximum absorption at 530nm. The colouring is proportional to the wavelength of light and makes it possible to quantify the reducing sugars in solution. In addition, 0.25ml of the dosing solution plus 1mL of distilled water and 0.25 mL of DNS (1g of DNS dissolved in 20ml of 10% NaOH; 30g of double Na and K tartrate dissolved in 50 mL of distilled water, both solutions were mixed and the volume made up to 100ml with distilled water) were added into test tubes. The tubes containing the different solutions were incubated in a boiling water bath for 5 minutes then immediately cooled in ice- cold water and 4 mL of distilled water added into each tube. The optical density of the solution was read at 540nm using a spectrophotometer and recorded.

Total protein content

The total nitrogen is determined after mineralization of the samples according to the Kjeldahl method (AFNOR, 1984) and assayed using a calorimetric technique (Devani *et al.*, 1989).

The Kjeldahl mineralization consisted of destroying all the organic substance contained in the powder corn using concentrated sulfuric acid (H₂SO₄) in the presence of the Dumazert mineralization catalyst (Merck). To do this, 1g of the powder corn sample added to 10mL of concentrated H₂SO₄, a pinch of mineralization catalyst was introduced into the mineralization flasks. These flasks were heated to hot in a digestion ramp for 6 hours until a clear solution was obtained. After cooling, the mineralized product was recovered in a volumetric flask and its volume made up to 50 mL with distilled water.

The colorimetric determination of nitrogen was based on the reaction of ammonia with acetylacetone and formaldehyde in aqueous medium to give a yellow product; 3,5-diacetyl 1,4-dihydrolutidine



Reaction of ammonia with acetylacetone and formaldehyde in aqueous medium (Hamtzsch reaction).

In a test tube, 0.1mL of the mineralized material is mixed with 1.2mL of sodium acetate (41g for 500mL of distilled water) and with 1.6mL of reactive solution (15mL of formaldehyde + 7.8mL of acetylacetone in 100mL of distilled water). The mixture was heated in a water bath at 97.5°C for 15 minutes and cooled in a stream of cold water, to lower the temperature of 30°C approximately, then 7.1mL of distilled H₂O was added to each tube and the optical density was read at 412 nm using a spectrophotometer. The protein content (Tp) was obtained by multiplying the nitrogen quantity with the conventional coefficient of conversion of nitrogen into protein which was 6.25. The quantity of nitrogen from each test sample expressed in grams was determined by referring to the calibration curve for ammonium sulphate and the crude protein content using the formula:

$$Tp = T(N_2) \times 6,25$$

Lipid Dosage

The total lipids in the corn samples were extracted with a Soxhlet according to the Russian method described by Bourelly, (1982). The test corn sample was dried in an oven at 105°C for 24 hours and introduced into a bag of dried filter paper and weighed. The oil was extracted using a Soxhlet with hexane for a period of 12 hours. The oil content was calculated at 0% moisture by the difference in weight of the sachet before and after the complete extraction of the lipids.

P₁ was the weight of the full sachet containing the test portion before processing paper plus test portion;

P was the weight of the full bag containing the test sample after oil extraction,

P₂ was the weight of the empty filter paper bag.

The oil content (Ph) per 100g of sample, expressed at 0% moisture was calculated using the formula:

$$\%Ph = [(P - P_2) / (P_1 - P_2)] \times 100$$

Dosage of mineral elements

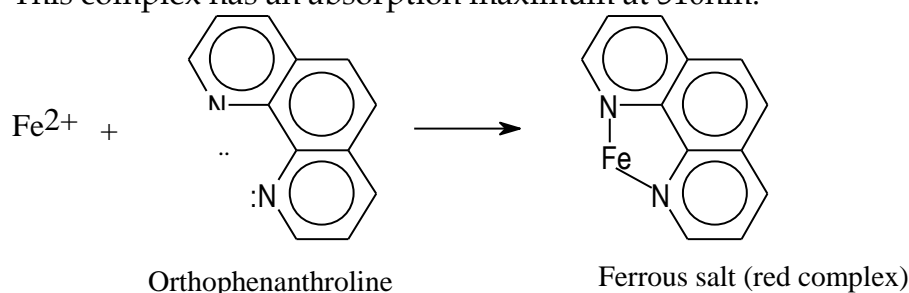
The general principle to obtain the various mineral elements in the corn sample was based on the dissolution of the metals and metalloids contained in the ashes in the form of

phosphate, sulphate and chloride salts of which did not volatilized during combustion are soluble in hydrochloric acid and will be carried away during filtration to constitute the ash solution while the incombustible mineral residues resulting from the combustion of organic compounds are insoluble in water and will constitute the filtration residue.

About 2mL of concentrated hydrochloric acid were introduced into the crucible containing the ashes and stirred to dissolve using a glass rod. Some distilled water was then added and heated for 10 minutes in a water bath until two thirds of the volume of the solution has evaporated. Later, 10ml of distilled water were added and filtered and the filtrate collected in a 50ml volumetric flask. The crucible was rinsed several times and added to the content of the filter before making up the volume to 50 mL with distilled water. The content of the flask was stoppered to avoid loss of water through evaporation and the various mineral content determined thus:

Determination of iron content of the corn

The iron is assayed with orthophenanthroline by colorimetry according to the method of Rodier, (1978). The principle is based on boiling an acid solution of ash released iron in ionic form (ferric iron) that is then reduced to the ferrous state by ascorbic acid and assayed by colorimetry, using the red coloration formed by the ferrous salts with orthophenanthroline. This complex has an absorption maximum at 510nm.



Reaction equation of iron II with orthophenanthroline

Acalibration curve was established using a standard iron solution (0.01 g of iron / l) prepared from a stock solution containing 70.023 mg / l of Mohr's salt ((NH₄)₂Fe(SO₄)₂·6H₂O) MW = 392.13. In a series of labelled test tubes, the iron solutions and the reagents were added in succession while stirring. The values generated are shown in table 6 below. For each sample, 10mL of the extracted ash were put in a test tube and 1mL of 1N hydrochloric acid solution added and the mixture boiled to ensure solubilisation of the iron. The solution was then cooled and made up to 10mL with distilled water. The test tubes were allowed to stand at room temperature for 30 minutes before reading optical density at 510nm using a spectrophotometer. The recorded values were extrapolated from the control curve.

Table 3: Calibration of the iron solution and its determination in ash solutions

Parameters	I	II	III	IV	V	VI	VII	Unknown (i)
Iron standard 0.01g / l (mL)	0	0.1	0.2	0.4	0.6	0.8	1	/
Distilled water (mL)	10	9.9	9.8	9.6	9.4	9.2	9	/
Sample (mL)	/	/	/	/	/	/	/	10
HCl N solution (ml)	1	1	1	1	1	1	1	1
Saturated sodium acetate solution (mL)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1% ascorbic acid (mL)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Orthophenantroline 1% (mL)	1	1	1	1	1	1	1	1
DO at 510 nm								
Iron (mg / L)	0	0.1	0.2	0.4	0.6	0.8	1	Qi

The amount of iron in each test sample, expressed in mg of iron per litre, was determined by referring to the calibration curve for Mohr's salt ((NH₄)₂Fe(SO₄)₂·6H₂O) (Iron standard daughter solution to 0.01g / L) of calibration range from 0 to 1mg / L and regression equation. DO = aQ + b.

Q: being the quantity of iron in the volume of sample analysed (0.1ml),

Tf: being the quantity of iron in 100g of dry matter,

V: the volume of ash extract,

Tc: the ash content of the sample,

C: the iron concentration of the sample,

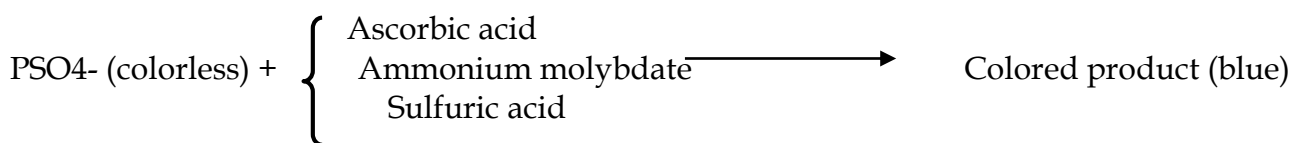
m, the weight of solubilized ash.

$$Tf(\%MF) = \frac{Cf \times V \times Tc}{m}$$

The result is the average of three determinations.

Determination of phosphorus content of the corn

The method and principle used was that described by Rodier (1978). The principle of this method is that in an acidic medium and in the presence of ammonium molybdate ((NH₄)₆MoO₂₄·4H₂O), the phosphates produce a phosphomolybdic complex which is being reduced by ascorbic acid producing a blue coloration determined by colorimetry. Some forms can be hydrolyzed during colouration and give phosphates. The colour development can be accelerated by the use of a catalyst (double antimony and potassium tartrate (C₄H₄O₇K₂Sb₂·1 / 2H₂O)). The coloured product formed exhibits a maximum absorption at 690 nm.



For the procedure to determine the phosphorus content of the corn, a calibration curve from a stock solution of potassium dihydrogenphosphate (KH_2PO_4 MW = 136g / mole) with a concentration of 14.315 mg / L in distilled water corresponding to 10 mg of phosphate / L was established. The reagent used for the standard solution was prepared by adding 20 ml of H_2SO_4 (5N) to 2mL of double antimony and potassium tartrate at 0.274g / L, then 12mL of vitamin C at 17.6g / L and 6mL of ammonium molybdate at 6% (W / V) were added. The standard solution and the various reagents were then introduced into a series of 25 mL flasks in succession while stirring and the calibrations shown in table 6. The optical densities of the tubes were read 20 minutes after using a spectrophotometer at 690 nm.

Table 4: Calibration of the solution of phosphates and its dosage in ash solutions

Parameters	Number of test tubes						Unknown (i)
	1	2	3	4	5	6	
N ° of tubes	1	2	3	4	5	6	Unknown (i)
Standard PO_4^{3-} - 10mg / l (ml)	0	1	2	3	4	5	/
Distilled water (ml)	20	19	18	17	16	15	/
Sample (ml)	/	/	/	/	/	/	20
Reagent (ml)	4	4	4	4	4	4	4
Distilled water QSP (ml)	25	25	25	25	25	25	25
OD at 690 nm							
Amount of PO_4^{3-} (mg)	0	0.01	0.02	0.03	0.04	0.05	Qi

The quantity of phosphate (mg) in the corn samples was obtained by referring to the calibration curve for potassium dihydrogen phosphate with a calibration range going from 0 to 0.05 mg using the equation.

$$\text{OD} = aQ + b.$$

Q: the amount of phosphate in the sample volume analysed with the spectrophotometer

The content of orthophosphates was calculated using the formula $TPO_4 = \frac{Tc \times 50 \times C \times V}{m}$

Knowing that 31 was the molecular weight of phosphorus and 95 (g / mole) the molecular weight of PO_4^{3-} the phosphorus equivalence (TP) was calculated using the relation and the result was an average of three determinations

$$TP(\%MF) = \frac{TPO_4 \times 31}{95}$$

TPO₄: the orthophosphate content,

TP: the phosphorus content,

m: mass of solubilized ash,

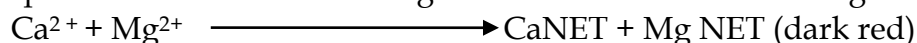
50 is the volume of the ash extract (mL) and

Tc: the ash content of the sample.

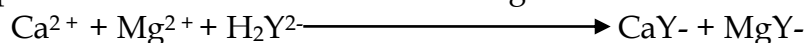
Determination of calcium and magnesium contents of the corn

The determination of the calcium and magnesium content of corn was carried out using the Titrimetric method (AFNOR, 1986). The method consists of a molar titration of Ca^{2+} and Mg^{2+} ions with a solution of disodium salt of ethylenediaminetetraacetic acid (EDTA) at pH

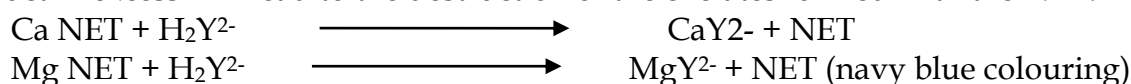
= 10. The indicator used is eriochrome black T (NET) which gives a dark red or violet colour in the presence of calcium and magnesium ions which later changes to navy blue colour.



The introduction of H_2Y^{2-} (EDTA) leads to the formation of the following colourless complexes from the free calcium and magnesium ions:



When all the Ca^{2+} ions and the Mg^{2+} have been complexed by H_2Y^{2-} , the introduction of this product in excess will lead to the destruction of the chelates formed with the NET.



The procedure to calibrate the EDTA solution (0.02 M) prepared with a solution of Ca^{2+} (0.01 mol / l) was performed as follows:

10ml of 0.01 mol / l calcium solution was put in a beaker and 2 mL of 2N NaOH and a pinch of the carboxylic acid calcone were added and the colour of the solution turns dark red or purple. Dose immediately with EDTA while constantly agitation of the beaker a navy blue colouration indicated the end point of the mixture.

The exact concentration of EDTA (C) expressed in moles / l was calculated using the formula:

$$C = 0.01 \times (V1 / V2),$$

Where 0.01 was the molarity of the calcium standard,

V1 the volume of the EDTA solution,

V2 the volume of the calcium standard.

To prepare the 0.01 g / l calcium solution, calcium carbonate (CaCO_3) was dried at 150 °C for 2 hours then weighed and about 1.001g which was introduced into a 500mL volumetric flask. It was then moistened with distilled water and 4M HCl was added drop wise until all the carbonate is dissolved. 200mL of distilled water was added into the dissolved carbonate and the mixture boiled for few minutes in order to eliminate the CO_2 . The mixture was cooled and a few drops of methyl red 0.1% (w / v) added. Later, 3M ammonia solution was added until the solution turns orange. 1000 mL of the solution was transferred into a volumetric flask and the volume made up with distilled water. 1mL of this solution contained 0.4008mg of Ca^{2+} or 0.01 mol / L.

The total concentration of Ca^{2+} and Mg^{2+} in the corn solution where TH (hydrotitrimetric titer) was expressed in mol/L using the formula

$$C_{\text{Ca}} \text{ or } C_{\text{Mg}} = C1V1 / V2$$

Where C1: concentration in mol / l of the EDTA solution (0.022 mol / l),

V1: volume in mL of the EDTA solution used for the titration,

V2: volume in ml of the sampled assayed.

The content of calcium (Tca^{2+}) and magnesium (TMg^{2+}) ions expressed in mol/L was calculated using formula:

$$T_{Ca}(\%MF) = \frac{T_C \times 40,8 \times C_{Ca} \times VT}{m}$$

40,8: molecular molar weight of calcium

VT: total volume of ash extracts in millilitres

m: test portion in mg

Tc: Ash content of the samples (g / 100g MF).

$$T_{Mga}(\%MF) = \frac{T_C \times M_{Mg} \times C \times VT}{m}$$

m: test portion in mg

Tc: Ash content of samples (g /100g MF)

C: Mg²⁺ concentration

MMg: Molecular mass of magnesium

VT: Total volume of ash extract in millilitres.

Determination of total hardness

In order to determine the total hardness of the corn (which is the total concentration of magnesium and calcium in a solution) stored in various conditions or hydrotitrimetric titer (TH), 5ml of the sample were added into a beaker and 4ml of a buffer solution 10 (dissolved 67.5g of ammonium chloride in 570 mL of 25% ammonical solution (v / v) plus 5g of sodium solution of Magnesium C₁₀H₁₂N₂O₈Na₂Mg and 1000ml of distilled water) and a pinch of NET were added. The solution turned dark red or purple at pH 10 ±0.1. A Dose of EDTA was immediately added into the beaker and mixture constantly agitated. Two determinations were made per sample.

For Calcium determination, 5ml of the corn sample from each storing condition was placed in a beaker and 2 mL of 2N NaOH and a pinch of Calcone carboxylic acid ([OH-2-sulfo-4-naphthylazo-1) -1 naphthalene carboxylic]) (C₂₁H₁₄N₂O₇S, 3H₂O) were added. The solution turns red at pH12 and was mixed and dose immediately with EDTA. The end point of the solution turns distinctly blue.

Determination of carbohydrates

Total Carbohydrates was expressed in percentage (%) after moisture, ash, fat and protein content had been determined. This was done using the formula.

% carbohydrate = 100% - [moisture content + ash content + total lipids + crude protein content].

Determination of microbial load

Preparation of serial dilution of samples

Fifty grams (50g), of each corn was aseptically transferred to a Waring Blender and 450ml of buffered dilution water and homogenized at approximately 8,000 rev/min as described by APHA. Dilutions of up to 10⁻³ were prepared in buffered dilution water as follows: 1 ml of suspension of sample was transferred into a tube containing 9 ml of sterile water and tube

thoroughly mixed. This gave a 10^{-2} . From this tube, 1 ml of sample was transferred into another tube containing 9. ml and mixed to have a 10^{-3} dilution

Determination of Total coliform load of corn samples

Coliform counts were determined by plating 1.0 ml of sample from the 10^{-3} dilution into a petri-dish. About 15 ml of Violet Red Bile (VRB) agar at approximately 45°C was poured to the plate and swirled gently to ensure mixing of sample and agar. Plates were overlaid with 4 to 5 ml of the same agar, allowed to solidify and then incubated for 24 hours at 37°C . Samples were plated in duplicate. Red colonies with dark centres were counted and the average multiplied by the dilution factor. Counts were expressed as CFU/g

Determination of the total viable bacterial load of corn samples

Total bacterial load of samples was determined using the pour plate method as described by ISO 8786.1. One millilitre of sample from the 10^{-2} was transferred into a 9 cm Petri dish. Nutrient agar (Sigma-Aldrich) (about 45°C) was then poured into the plate and the plate swirled to mix the medium and sample. Plates were allowed to solidify and then incubated at 37°C for 48 hours. Samples were inoculated in triplicate. Total bacterial load was determined by multiplying the counts by the dilution factor. Counts were expressed as CFU/g.

Determination of the fungal load of corn samples

Total fungal load of weaning food samples was determined using the ISO horizontal methods for the enumeration of yeasts and moulds in foods as described by ISO 8786.1 One micro litre suspension of the corn containing small quantities of polysorbitan 80 (break up clumps of mould spores and conidia), was spread over the surface of Sabouraud Dextrose agar (Sigma-Aldrich). Antibiotic was also added to inhibit bacteria growth. Plates were allowed to solidify and then incubated at room Temperature for 5 to 7 days and then examined daily for growth. Total fungal load was determined by multiplying the counts by the dilution factor. Counts were expressed as CFU/g.

Data Analysis

The analysis included descriptive statistics (that is tabulation and percentages). All determinations were carried out in triplicate and data were subjected to analysis of variance (ANOVA). Statistical analysis was performed using SigmaStat version 3.5 (Point Richmond, CA, USA). Multiple comparison within variables was performed using the Tukey test post hoc. Statistical significance between parameters was set at probability (p) value < 0.05 .

4. Results and Discussion

Farmers who preserve corn

Farmers in Bamngam village preserve their corn. Out of the 50 farmers who answered the questionnaires, 100% of the farmers indicated that they preserve corn.

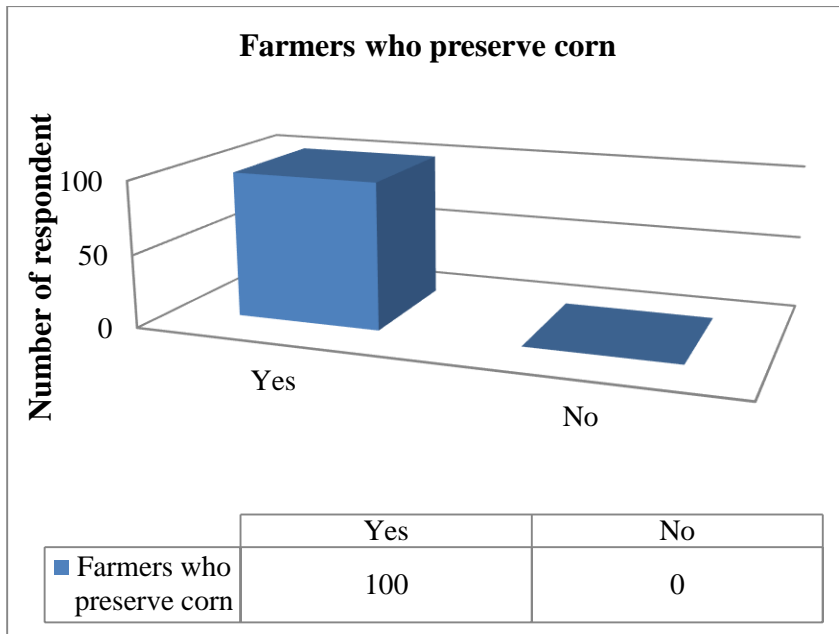


Figure 8: Farmers who preserve corn in Bamngam village
Duration of corn preservation

Out of the 50 farmers who answered the questionnaires, 80% of the farmers preserved corn for one year, 15% preserve their corn for above one year and only 5% of the farmers preserved corn for less than one year.

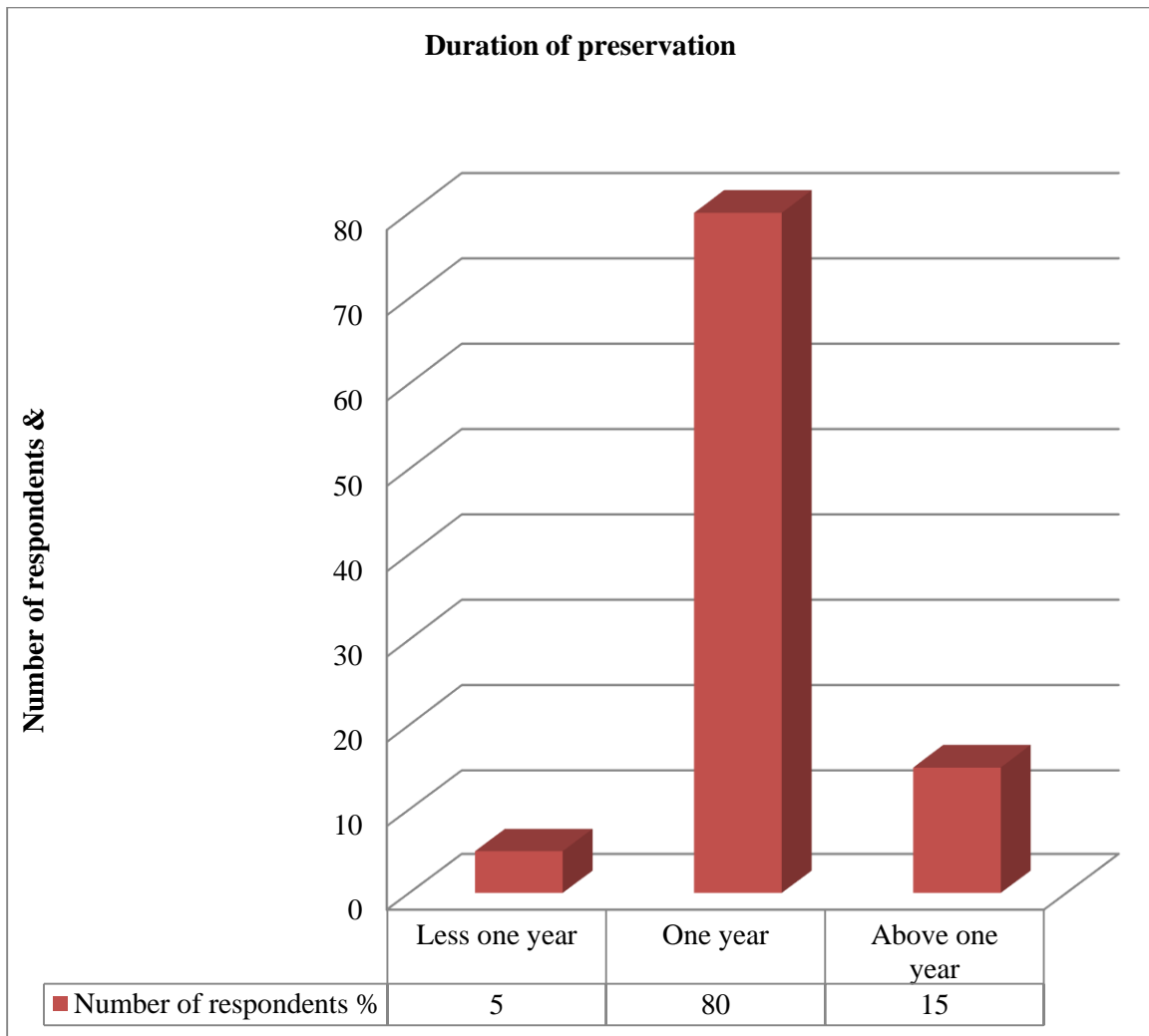


Figure 9: Duration of preservation of corn in Bamngam village

Preservation techniques

Of the 50 farmers used in this study, 100% of the farmers use local preservation techniques to preserve corn.

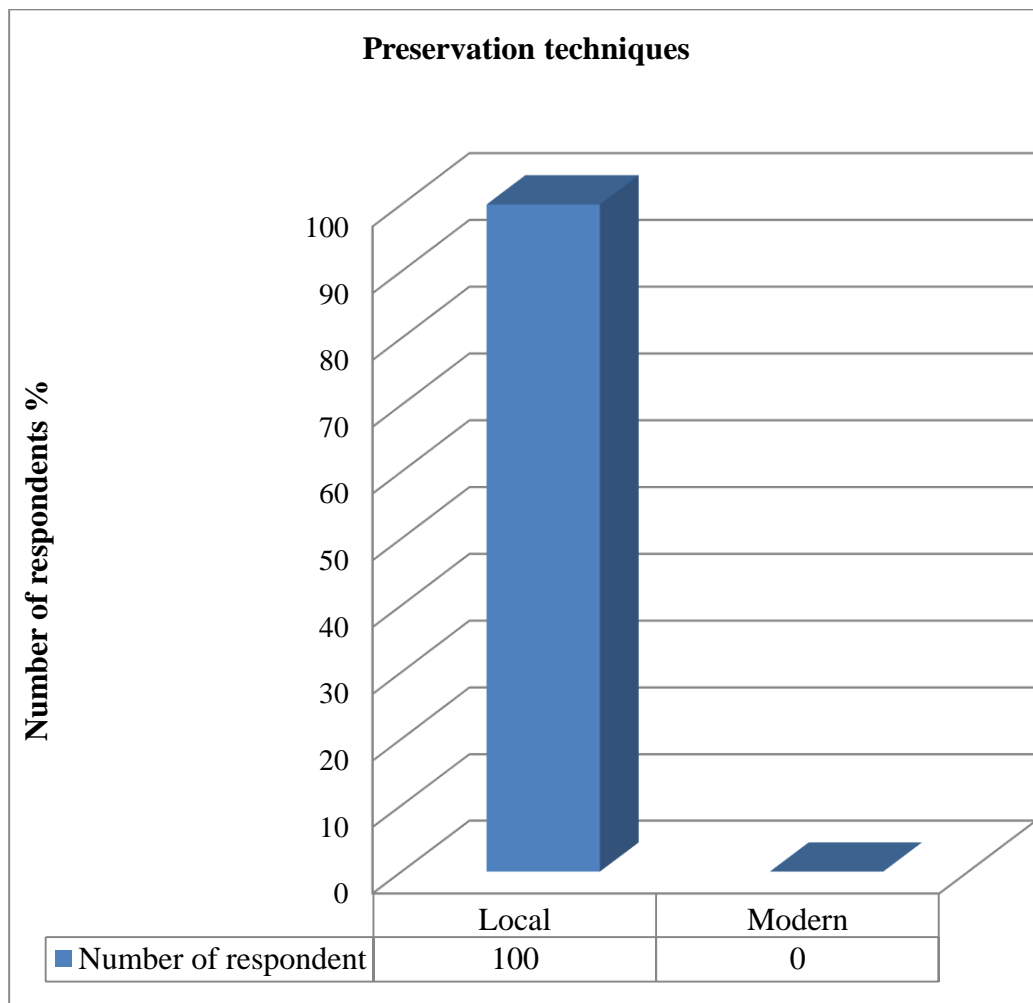


Figure 10: Preservation techniques used by farmers in Bamngam village

Colour of corn cultivated

Out of the 50 farmers interviewed, 90% of them cultivate yellow corn and only 10% cultivate the white corn.

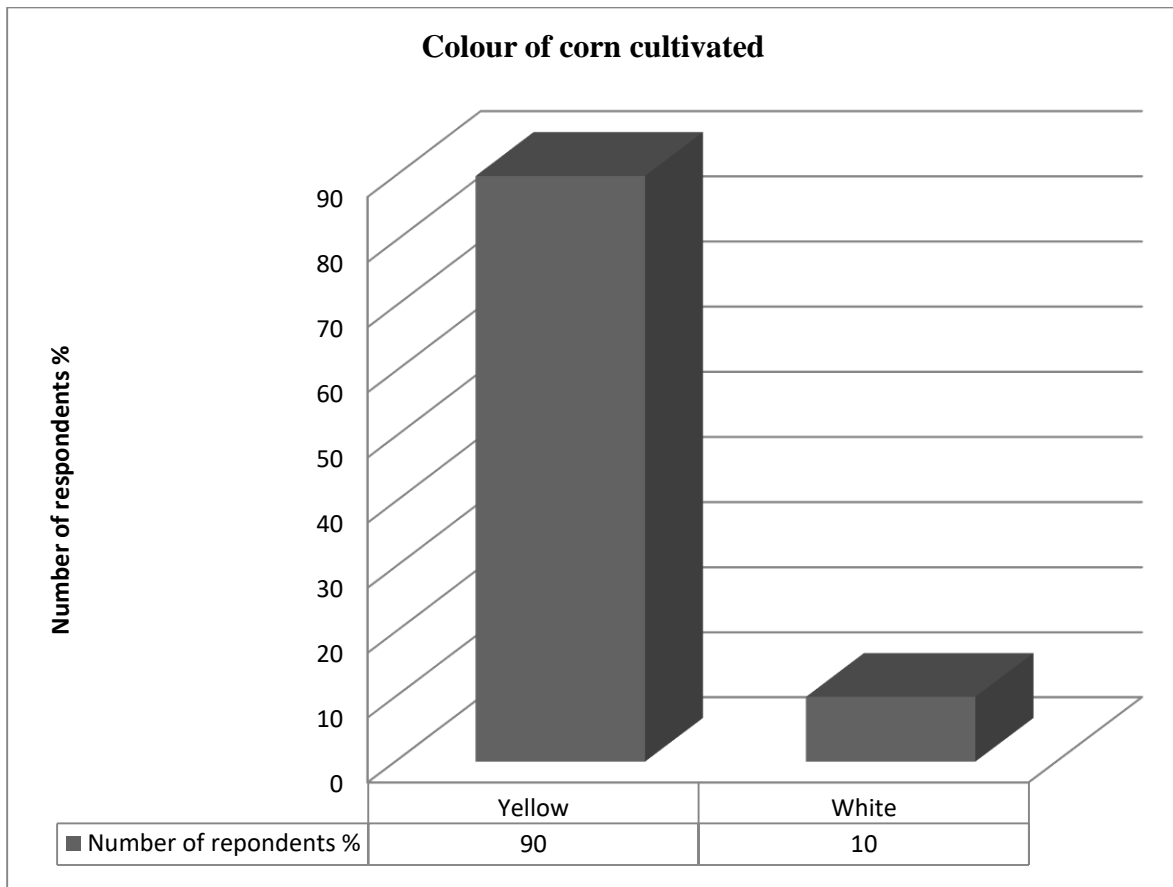


Figure 11: Colour of corn cultivated in Bamngam village

Local corn storage methods in Bamngam village

Three main local storage methods for corn in the Bamngam village were identified: storage in barns, husk hanging outside under shades and storage in sealed containers (hermetic storage). Out of the 50 farmers interviewed, 60% of the famers stored corn in barns, 20% hung the corn cobs outside under shades (husk hanging) and 20% stored corn in sealed plastic containers as shown in the figures below.

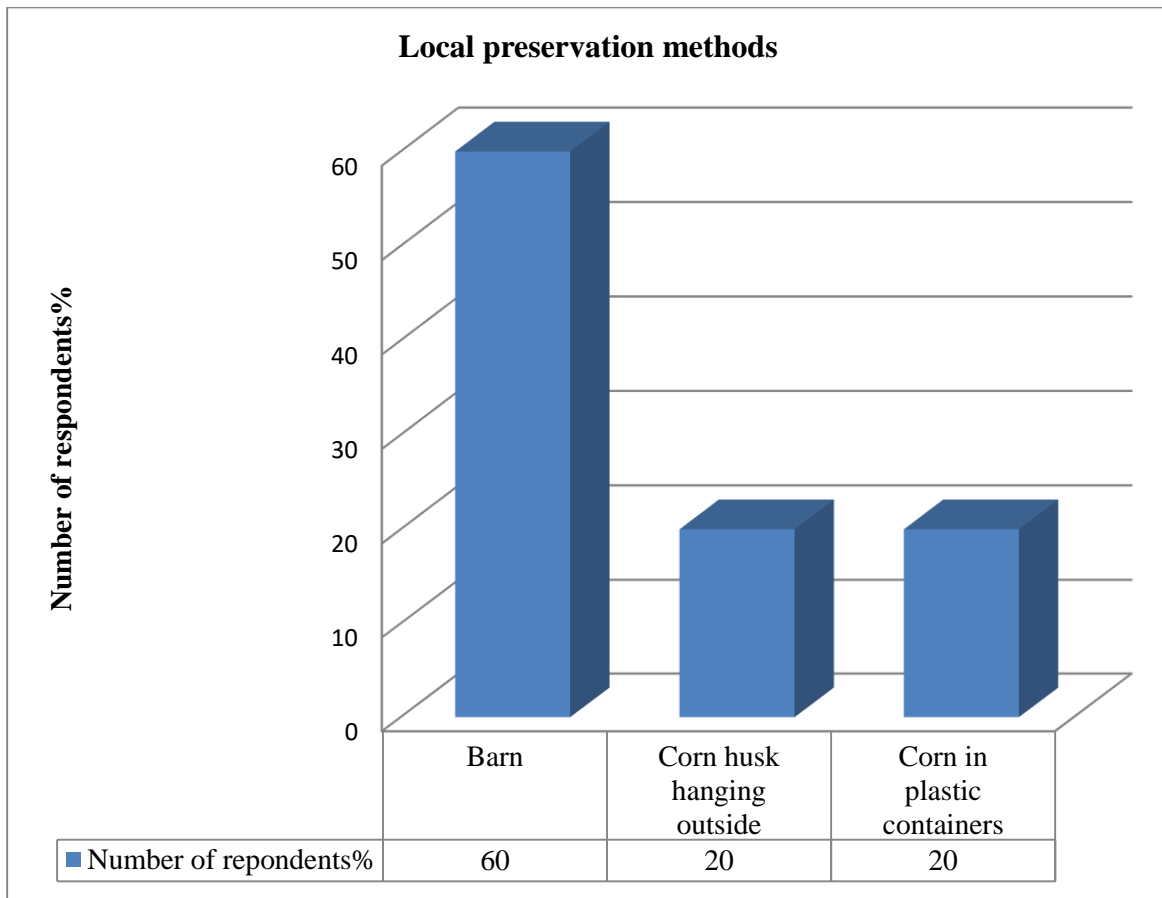


Figure 12: Local preservation methods used in Bamngam village

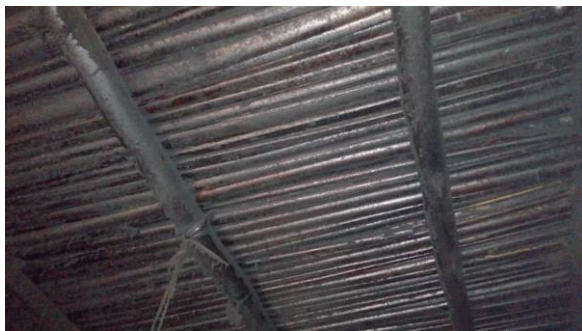


Figure 13: Surface view of a local kitchen barn (a); Corn stored in the barn (b)



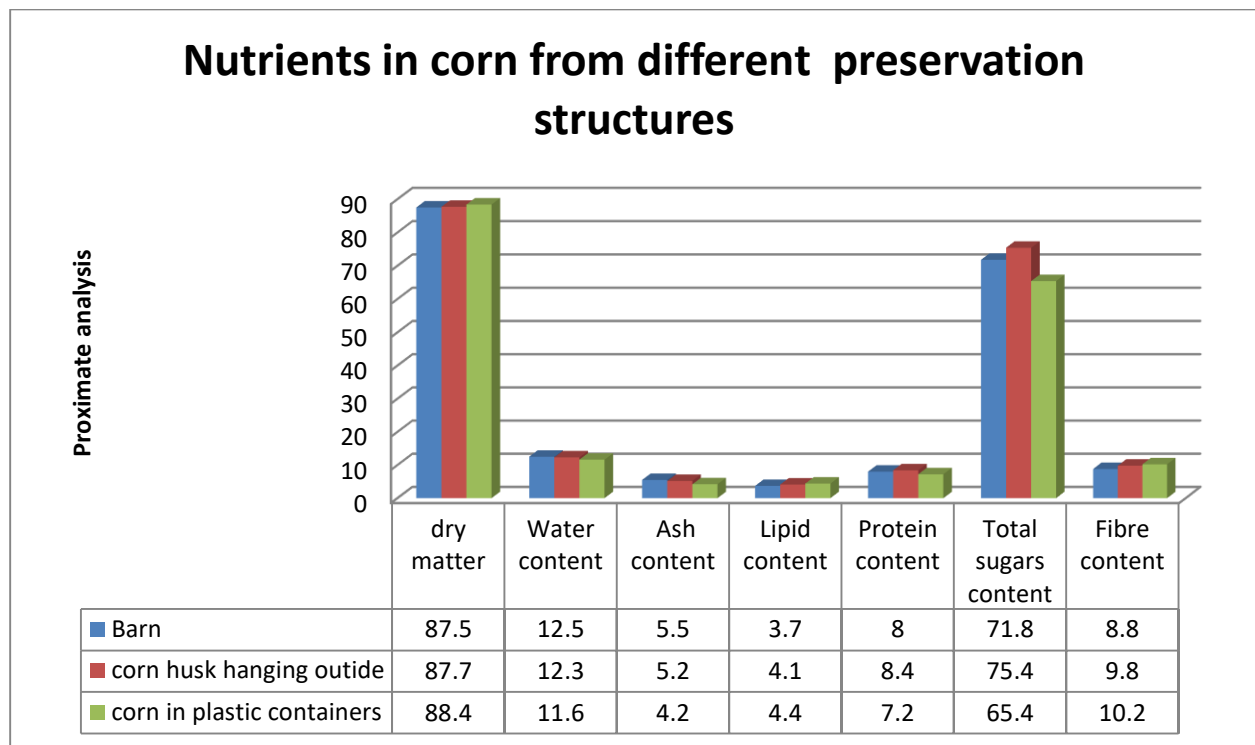
Macronutrients analysis of yellow corn stored under different local conditions

One Way ANOVA and the Tukey multiple comparison test (post hoc test) was used to evaluate variations in the nutritional content of yellow corn that were of healthy condition preserved under various local methods. The results showed that the dry matter content (88.44 ± 0.56) and fibre content (10.16 ± 0.96) of yellow corn from hermetic storing condition were significantly ($p < 0.05$) higher than in those from the barns and husk hanging storing conditions (Table 8). Conversely, the water content (11.55 ± 0.56) and protein content (7.16 ± 0.24) of yellow corn from the hermetic storing conditions were significantly lower ($p > 0.05$) than the content of these nutrients in yellow corn from other storing methods (Table 8). These results were the same for corn from barns and husk hanging outside under shades. In addition, we recorded no significant ($p > 0.05$) difference in the ash, lipid and total sugar contents in any of the corn samples from the three local storing conditions (Table 5).

Table 5: The Tukey multiple comparison of nutrient composition of corn from three local storage structures

Storage method	Mean \pm standard deviation of nutritional parameters						
	Dry matter content (%)	Water content (%)	Ash content (g/100g)	Lipid content (g/100g)	Protein Content (g/100g)	Total sugars content (g/100g)	Fiber content (g/100g)
Barn	$87.46 \pm 0.17b$	$12.53 \pm 0.17a$	$5.54 \pm 0.41a$	$3.74 \pm 0.42a$	$8.04 \pm 0.84a$	$71.68 \pm 1.64a$	8.83 ± 0.43
Husk Hanging outside	$87.66 \pm 0.24b$	$12.33 \pm 0.24a$	$5.17 \pm 0.68a$	$4.14 \pm 0.06a$	$8.43 \pm 0.44a$	$75.36 \pm 1.81a$	9.75 ± 0.80
Plastic container	$88.44 \pm 0.56a$	$11.55 \pm 0.56b$	$4.20 \pm 1.03a$	$4.43 \pm 0.25a$	$7.16 \pm 0.24b$	$65.41 \pm 1.6a$	10.16 ± 0.96
Total	87.85 ± 0.55	12.14 ± 0.55	4.97 ± 0.89	4.11 ± 0.38		70.82 ± 4.59	9.58 ± 0.89
F	6,022 *	6,022 *	2.50ns	4.30ns	3,920 *	2.37ns	25.95 **

ns: Not significant ($p > 0.05$). *: Significant difference ($p < 0.05$). F: Fiduciary limits.
Note: For the same column, the means bearing the same letter do not present any significant differences according to the Tukey test at the 5% level.



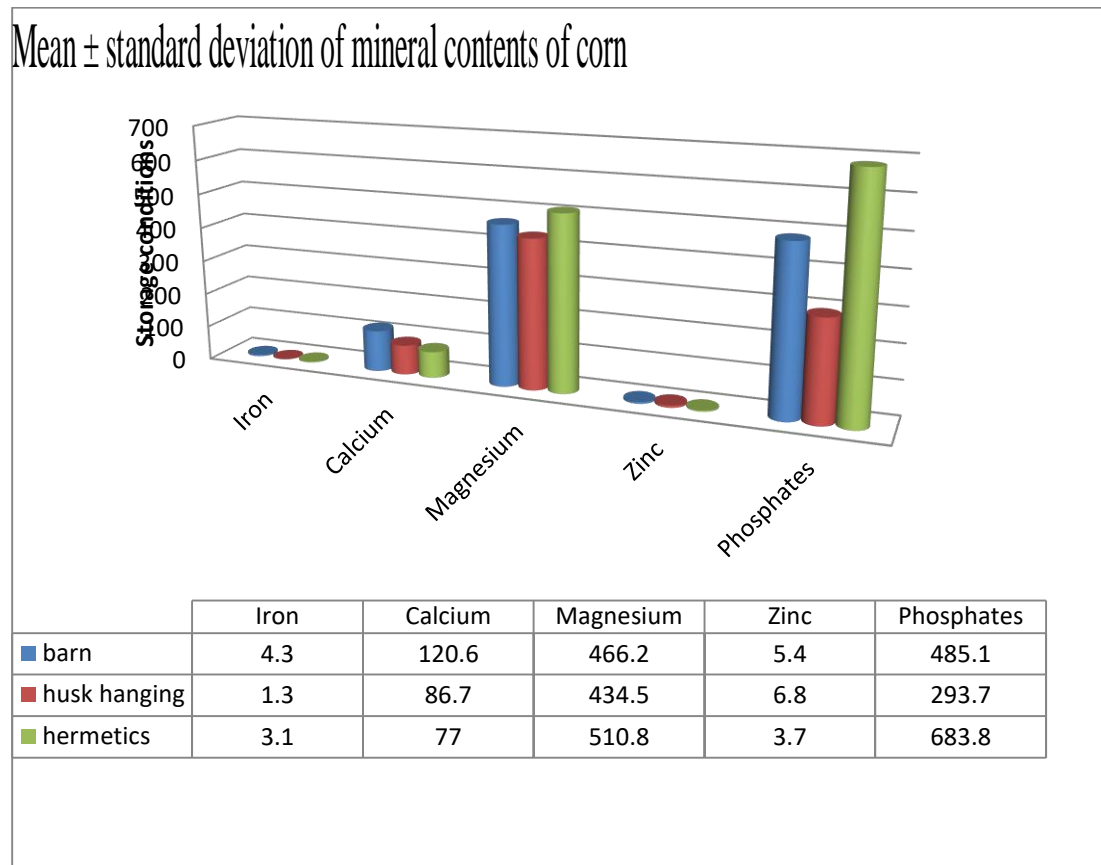
Micronutrients analysis of yellow corn stored under different local conditions

One Way ANOVA and the Tukey multiple comparison test (post hoc test) was used to compare the mineral content of yellow corn that were of healthy conditions obtained from the three different storage structures. We noticed that there was a significant difference between the mean iron content (mg/100g) ($F = 31.50, p < 0.05$) and phosphate content (mg/100g) ($F = 27.47, p < 0.05$) of corn from the different storage conditions and corn from barn storing (Mean Fe (mg/100g): 4.34 ± 0.21) and husk hanging storing (Mean Fe (mg/100g): 1.26 ± 0.19) conditions recorded respective significant ($p < 0.05$) higher and lower iron content than corn sample from hermetic storing condition (Mean Fe (mg/100g): 3.13 ± 0.77). Conversely, corn samples from hermetic and husk hanging outside recorded respective significant ($p < 0.05$) higher (683.83 ± 93.49) and lower (293.66 ± 33.82) phosphate contents than corn from barn storing (485.07 ± 50.80). In addition, the zinc content (6.80 ± 1.18) of corn from husk hanging condition and the calcium content (120.61 ± 28.09) in corn from the barn storing conditions were significantly ($p < 0.05$) higher than the content in other storing conditions even though there was no significant ($p > 0.05$) difference in these mineral content in corn of different storing structures (Table 6). There was no significant difference between ($F = 1.813, p > 0.05$) and within ($p > 0.05$) the magnesium content of yellow corn from the three different storing conditions.

Table 6: Tukey multiple comparison of mineral composition of corn from three local storage structures

Storage condition	Mean \pm standard deviation of mineral contents of corn				
	Iron (mg/100g)	Calcium (mg/100g)	Magnesium (mg/100g)	Zinc (mg/100g)	Phosphates (mg/100g)
Barn	4.34 \pm 0.21a	120.61 \pm 28.09a	466.19 \pm 23.16a	5.44 \pm 1.17ab	485.07 \pm 50.80b
Husk hanging	1.26 \pm 0.19c	86.73 \pm 4.41ab	434.51 \pm 51.59a	6.80 \pm 1.18a	293.66 \pm 33.82c
Hermetic	3.13 \pm 0.77b	76.96 \pm 13.51b	510.77 \pm 63.93a	3.74 \pm 0.58b	683.83 \pm 93.49a
Total	2.91 \pm 1.40	94.76 \pm 25.32	470.49 \pm 54.06	5.32 \pm 1.59	487.52 \pm 17.7
F	31.50 **	4.76ns	1.813ns	6.77 *	27.47 **

ns: not significant ($p > 0.05$); *: Significant ($p < 0.05$); F: fiduciary limit.
For the same column, the means bearing the same letter do not present any significant differences according to the Tukey test at the 5% level



Pathological and morphological evaluation of yellow corn from the different storing techniques

In this study, we noticed that 81% of yellow corn from hermetic storing was of good health condition (viability) than corn from the barn and husk hanging storing structures. Furthermore, most seeds (80%) from the barn storing were noticed to be mechanically damaged than seeds from other storing conditions (Table 10). Also, 21% of corn from the husk hanging structure were malformed than corn from the barn (9%) and hermetic (9%) storing. In addition, we noticed that 70% of the corn from the husk hanging condition were infested and damaged by insects or attacked by mold/rancid (12%) and contaminated with animal impurities/ dead insects (20%) (Table 7).

Microbiological analysis of yellow corn

The analysis was carried out to determine microorganisms present in corn. The following microorganisms were analysed total aerobic mesophilic flora, total coliforms, yeast and molds, clostridium sulfite and *Salmonella*.

In this study, it was observed that yellow corn samples from the three storing conditions were not contaminated with Clostridium sulfite reducing bacteria. Though Coliform bacteria were detected in all the corn samples, they were of acceptable levels. Salmonella bacteria species were detected in all the corn samples but the levels were satisfactory except corn from the barn the recorded acceptable levels. All the corn samples recorded non satisfactory levels of yeast and molds contamination. The total aerobic mesophilic flora of the corn samples were not satisfactory excluding corn sample from the hermetic storing that recorded acceptable level of contamination (Table 8).

Table 8: Analysis of microbiological qualities of yellow corn based on the storing condition.

Storage condition	Microbiological parameters				
	Total aerobic mesophilic flora	Total coliforms	Yeasts and molds	Clostridium sulfite-reducing	Salmonella
Corn from barn	3.01x10 ³ (NS)*	0.50x10 ² (AT)	7.5x10 ² (NS)	Absent (S)	5.75x10 ² (AT)
Corn hung outside	6.07x10 ³ (NS)	0.60x10 ² (AT)	0.5 x10 ² (NS)	Absent (S)	0.3x10 ² (S)
Corn from plastic container	1.13x10 ³ (AT)	0.50x10 ² (AT)	9.5x10 ² (NS)	Absent (S)	0.8x10 ² (S)

*:Letters in bracket shows the indicator level (NS: not satisfactory; AT: Acceptable; S: Satisfactory;)

Discussion

This study was aimed at identifying the different storing techniques of yellow corn in the Bamngam village and assess the nutritional content of the corn preserved under the different local storage conditions in this community.

Preservation of corn is an important aspect of the farmers in Bamngam village. All the farmers in this community preserve their corn for future use. Corn is stored in order to cover food requirement and future cash needs (Sekumade and Oluwatayo, 2009). The farmers of Bamngam preserve corn for food requirement and to sell excesses to purchase other basic needs. The staple food of the people in this village is corn fufu which is made from corn. The farmers of Bamngam preserve their corn less than one year, one year and above year. We observed that more farmers preserve their corn for one year. It is so because most farmers cultivate on small pieces of land, using rudimentary tools, poor storage structure, poor preservation techniques, consume food made out of corn almost on daily basis and finally the corn farming season is less than nine months so the yield can only be preserve for a year.

Among the preservation techniques available for corn storage, farmers of this community still use the local preservation techniques to store corn. The local techniques are still in use because there are no agricultural programmes or structures in the village to educate the farmers on preservation techniques. In addition, farmers could go to other places to learn

about storage techniques but they are adamant to it and prefer the traditional techniques because it is cheap, readily available and have no effects on their health nor the environment.

The farmers of the Bamnagam village cultivate the white and yellow corn varieties. We saw that many farmers cultivate the yellow variety of the corn. The reasons are that the yellow corn matures faster as compared to the white corn. Also, its appearance when prepared as food is more appealing to the consumer.

Among the three local storage methods of yellow corn identified in the community, storage in barns was commonly used by the farmers. This is because the farmers do not spend money constructing contemporary storage vessels like the crib and silo, and they prefer storing the corn in the same living houses and/or in kitchens because they are safe. Also, the solar energy emitted from the aluminium roofing sheets and heat from burning of wood/plant materials helps in drying the corn while the smoke serve as preservative.

The dry matter content and fibre content of yellow corn from the hermetic storage were higher compared to the content from other storing conditions. This could be explained on the basis that corn stored in plastic containers is not directly exposed to the environment and may experience minimal daily fluctuations in atmospheric temperature and humidity compared to corn from the barn and husk hanging outside on ceilings. Furthermore, insects, birds, fungi and rodents do not easily have access into corn stored in plastic containers and this may indirectly reduce their activities on the corn that may possibly affect its fibre content.

Logically, dry matter is inversely proportional to water content. This was in conformity with our study as corn under the hermetic storage condition recorded significant lower water content compared with corn from the other storing methods. In addition, we observed that corn stored in sealed plastic containers had lower protein content and the result was similar to that of Enyisi *et al.* (2014) reported in Kaduna Nigeria. This result cannot be clearly explained in this study. However, this could be related to enzymatic activity on the corn stored in these plastic containers as they may have relatively suitable conditions for their functioning.

We noticed that storage condition did not significantly affect the ash, lipid and total sugar content of yellow corn. However, the values for lipids and total sugar content in this study were similar to those reported by Okonkuro and Aghsrandi in 2007 from the analysis of corn found in local African market. This could be suggested that the content of these macronutrients in stored corn are stable.

Surprisingly in this study, we observed that there were significant variations in the mineral contents of corn samples from the different storing structures excluding the magnesium content. We expected insignificant variations in the results since the ash content showed no significant difference irrespective of the storage technique. Any possible explanation about this was limited.

Concerning the pathological and morphological characteristics of the corn samples, corn samples that were stored in plastic container had more healthy seeds compared to samples

from other storing conditions. This could possibly be related to the mechanical protection of the corn offered by the vessels and other internal conditions such as limited air that do not favour the activities of pest, molds, and other microorganisms in this storing condition unlike corn from the barn and husk hanging storing conditions that are exposed to these factors. Corn samples from barns and husk hanging outside were more prone to mechanical damaged than corn from hermetic storing structure. This is because corn cobs for storage through these methods are often gathered in piles and can be subjected to mechanical damage resulting from human handling during and after harvest, and environmental conditions wind. Higher numbers of malformed seeds were in corn samples from husk hanging and this could be attributed to the handling of the corn after harvest, preparation for hanging and during storage. In addition, corn samples from husk hanging outside were more subjected to insect damage, mold/rancid attacks and contamination by animal impurities/dead insects. This is because corn stored by this method are easily exposed to insects' attacks like weevils, animal contaminations such as waste from rats, birds, and fungi/other microorganisms' infestations.

5. Conclusion and Recommendations

Conclusions

The main objective of this study was to analyse the effect of local preservation methods on the nutritional content of yellow corn. Findings show that the population of Bamngam uses local methods for storing corn and these techniques included corn stored in barns, husk hanging outside on shades and hermetic storage (corn stored in plastic containers). Furthermore, these traditional storing methods affected the nutritional quality of yellow corn such as the dry matter content, water content, protein content and the fibre content. In addition, these storing structures also affected the micronutritional quality of the yellow corn such as the iron, calcium, zinc and phosphate contents excluding magnesium. The best storage method seen in this study was the hermetic storage method. Findings therefore show that we accept the alternative hypothesis that local preservative techniques affect the nutritional quality of yellow corn and the commonest storage method was using the barn.

Recommendations

Corn is a staple food in Bui Division we recommend that more attention be paid to storage facilities to avoid post-harvest losses. Hermetic storage facilities should be constructed for storage as they provide good storage conditions which hinder conditions that cause spoilage in corn and keeping the corn intact. Furthermore, the shelling or dehusking of corn before storage in open air should be discouraged as it exposes the corn to dust, microorganisms and rodents.

6. References

- Adesina J. M., Nameirakpam B., Dinabandhu S, Yallappa R., (2019). Traditional Methods of Food Grains Preservation and Storage in Nigeria and India. *Annals of Agricultural Sciences* 64: 196–205s
- Agona A and Muyinza J. N. H., (2008).An overview of maize in Uganda, Postharvest Programme NARO Uganda.

- Akob C. A. and Ewete, F. K. (2010). Control of *Sitophilus zea mais* Motschulsky (Coleoptera: Curculionidae) with local plant materials in the western highlands of Cameroon. *Journal of the Cameroon Academy of Sciences* 9 No. 1
- Asghar A., Ali A., Sayed H. W., Khaliq T. and Abid A. A., (2010). Growth and yield of maize (*Zea mays*) cultivars affected by NPK Application in Different preparation. *Pakistan Journal of science* 4,62;211
- Ashok Kumar, S. L. Jat, Ramesh Kumar and O. P. Yadav., (2013). Maize production systems for improving resource-use efficiency and livelihood security Directorate of Maize Research, Pusa Campus, New Delhi- 110 012, 123p. ISBN 978-81-928624-0-8
- Brigid McKeivith. (2004). Nutritional Aspects of Cereals. Final Report to the Home row Cereal Authority. Copyright British Nutrition Foundation pp 1-53
- Costa Simon J., (2014). Reducing Food Losses in Sub-Saharan Africa (improving Post-Harvest Management and Storage Technologies of Smallholder Farmers.) UN World Food Programme | P.O. Box 7159 | Kampala, Uganda
- Dejene M, Yuen J, Sigvald R. (2006). Effects of storage methods, storage time and different agro-ecological zones on chemical components of stored sorghum grain in Hararghe, Ethiopia. *Journal of Stored Products Research*, 42:445–456
- Dongli Ma, Juntao Li, Chengfei Huang, Fengjuan Yang, Yi Wu, Ling Liu, Wei Jiang, Zhicheng Jia, Peijun Zhang, Xuezhen Liu, and Shuai Zhang. (2019). Determination of the energy contents and nutrient digestibility of corn, waxy corn and steam-flaked corn fed to growing pigs. 32, No. 10:1573-1579 *Asian-Australasian Journal of Animal Sciences* <https://doi.org/10.5713/ajas.18.0713> pISSN 1011-2367 eISSN 1976-5517
- Dubale Befikadua. (2014). Factors Affecting Quality of Grain Stored in Ethiopian Traditional Storage Structures and Opportunities for Improvement. *International Journal of Sciences: Basic and Applied Research (IJSBAR)* 18(1), 235-257
- Emily T. Nuss and Sherry A. Tanumihardjo, (2010). Maize: A Paramount Staple Crop in the Context of Global Nutrition. *Comprehensive Reviews in Food Science and Food Safety*. Doi: 10.1111/j.1541-4337.2010.00117.x 9,2010
- Enyisi, I., V. Umoh, C. Whong, I Abdullahi and O. Alabi. (2014). Chemical and nutritional value of maize and maize products obtained from selected markets in Kaduna State, Nigeria. *Afr. J. Food Sci. & Technol.*, 5(4): 100-104.
- (FAO) Food and Agricultural Organization of the United Nations (2012). <http://faostat3.fao.org>.
- Food and Agriculture Organization of United Nations. (2014). Global Initiative on Food Losses and Waste Reduction; FAO: Rome, Italy
- FAO, (2017). Nutrition-Sensitive Agriculture and Food Systems in Practice Options for Intervention. Food and Agriculture Organization of the United Nations Rome, 2017
- FAO (Food and Agricultural Organization). (2003). Food Outlook. No 4. FAO Global Information and Early Warning System on Food and Agriculture. FAO, Rome.
- FAO (Food and Agricultural Organization). (2006). Maize: international market profile. Grains team food and agriculture organization of the United Nations economic and social department trade and markets division. Available at: <http://www.fao.org/es/esc/common/ecg/54/en/MaizeProfile.pdf>.

- FAO (Food and Agricultural Organization). (2011). Missing food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. Available at http://siteresources.worldbank.org/INTARD/Resources/MissingFoods10_web.pdf.
- FAO (Food and Agricultural Organization). (1992). Maize in Human Nutrition. FAO Food and Nutrition Series No. 25. 1-160. Rome: FAO.
- Gumus R.H. and Ketebe E. (2013). The Effect of Temperature on Drying Rate of Agro Food: Corn (Maize) and Ogbono (*Irvingia Gabonnensis*) *IOSR Journal of Engineering (IOSRJEN)* 3 (3) 36-42
- Harold Macauley. (2015). Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat. Abdou Diouf Internal Conference Centre Dakar, Senegal
- Hui H. Y. (2006). Handbook of food science, technology and engineering Volume 1. Published in 2006 by CRC Press Taylor and Francis Group 6000 Broken Sound parkway NW, Suite 300 Boca Raton, FL 33487-2742
- Ikram U., Muhammad A. and Arifa F. (2010). Chemical and Nutritional Properties of some Maize (*Zea mays*) Varieties Grown in NWFP, Pakistan. *Pakistan journal of Nutrition* 9(11):11113-11117
- Ine de Groot, (2004). Protection of Stored grains and pulses. Printed by: Digigrafi Wageningen, the Netherlands ISBN: 90-77073-49-3 pp 1-78
- Ivan Maksymiv, (2015). Pesticides: Benefits and Hazards. *Journal of VasylyStefanykPrecarpathian National University* <http://jpnu.pu.if.ua> 2 (1) 70-76
- Jacek J., Szambelan K., Miettinen H., Nowak W., Czarnecki Z., (2008). Effect of the Corn Grain Storage Method on Saccharification and Ethanol Fermentation Yield. *Acta Sci. Pol., Technol. Aliment.* 7(1), 19-27.
- Jayas Digvir S. (2012). Storing Grains for Food Security and Sustainability. *Agric Res* 1(1):21-24
- Jayas D.S and White N.D.G, (2003). Storage and drying of grain in Canada: low-cost approaches, *Food Control* 14 pp. 255-261
- Jéan du Plessis, (2013). Maize production. Directorate Agricultural Information Services Department of Agriculture in cooperation with ARC-Grain Crops Institute. Private Bag X144, Pretoria, 0001 South Africa
- Kalidas D. S and Ma B. L. (2001). Corn Crop Production: Growth, Fertilization and Yield. ISBN 978-1-60741-955-6 © 2009 Nova Science Publishers, Inc. AAFC-ECORC Contribution No. 08-953.
- Kamlesh D, Tajamul R. S and Pradyuman K. (2016). Maize – A potential source of human nutrition and health: A review. Food Science & Technology Review Article. *Cogent Food & Agriculture* 2: 1166995 <http://dx.doi.org/10.1080/23311932.2016.1166995>
- Kedwo Aggrey, (2015). Traditional storage practices on the quality of maize a case study in the Shai Osudoku District in the Greater Accra Region. University of Ghana <http://ugspace.ug.edu.gh>
- Ken Bullen, (2007). Insect Control in Stored Grain. DPI&F, Plant science, Toowoomba, Queensland. Pages 1 to 20
- Kevin Nnanye Nwaigwe, (2019). An Overview of Cereal Grain Storage Techniques and Prospects in Africa. *International Journal of Bioengineering & Biotechnology.* 4 (2) , pp. 19-25.

- Kidist Hailu Demeke. Nutritional Quality Evaluation of Seven Maize Varieties Grown in Ethiopia. *Biochemistry and Molecular Biology*. 3 (2), pp. 45-48.
- Kumar, Ashok, Jat, S. L., Kumar, Ramesh, Yadav, O. P, (2013). Maize production systems for improving resource-use efficiency and livelihood security Directorate of Maize Research, Pusa Campus, New Delhi- 110 012, 123p.
- Kumar, D., and Jhariya, N. A, (2013). Nutritional, medicinal and economical importance of corn: A mini review. *Research Journal of Pharmaceutical Sciences*, 2, 7-8.
- Kshirod R Bhattacharya, (2011). Rice quality. A guide to rice and analysis. Woodhead Publishing Limited, 2011 oxford Cambridge Philadelphia New Delhi
- Langsi D. J. , E. N. Nukenine¹, C. N. Fokunang, C. Suh, A. W. Agwanande, T. H. Katamsadan (2017). Evaluation of post-harvest maize treatment, phyto-insecticide use on maize varieties in Mezam Division. *International Journal of Agronomy and Agricultural Research (IJAAR)* ISSN: <http://www.innspub.net> 10 (3) p. 1-17
- Magan, N.; Aldred, D. (2007). Post-harvest Control Strategies: Minimizing Mycotoxins in the Food Chain. *Int. J. Food Microbial*. 119, 131-139.
- Niamketchi L., Olivier C, Didier A., Yves N., Fulbert N., Pierre E., Désiré K and Godi H., (2015). Descriptive Study of Maize Storage Methods (*Zea Mays*) Used in Rural Environment in Three Zones of Cote D'ivoire. *Global Advanced Research Journal of Agricultural Science* (ISSN: 2315-5094) 4(10) pp. 663-672
- Okonkwo, C and Agharandu,U (2007). Proximate and Vitamin Composition of Selected Cereals commonly used for weaning Babies' Food Preparation in South Eastern Nigeria, *Journal of Biology, Agriculture and Healthcare*, 7:22-
- Olakojo S. A and Akinlosotu T.A, (2004). Comparative study of storage methods of maize grains in South Western Nigeria. *African Journal of Biotechnology* 3 (7), pp. 362-365
- Olufunso O. , Oluwole S., and Ariwoola. (2019). Comparative Proximate Composition of Maize (*Zea mays* L.) Varieties Grown in South-western Nigeria. *International Annals of Science* ISSN: 2456-7132 7(1) pp. 1-5.
- Pardeep K., Shankar L., Bhupender K. and Vishal S., (2019). Nutritional quality improvement in maize: Progress and Challenges. *Indian Journal of Agricultural Sciences* 89(6): 895-911
- Paulo C. C., Lélia V. M., Lucas J. C and Maria G O. (2016). Drying and Storage of Corn Grains for Ethanol Production in Brazil. *Bioscience Journal* DOI: 10.14393/BJ-v32n5a2016-32754
- Rahmawati. R. Ratih D., Purwiyatno H., Dedi F. and Nur R. (2013). Isolation and Identification of Microorganisms During Spontaneous Fermentation of Maize. *J. Teknol. dan Industri Pangan* 24 (1)
- Ranum P, Juan P. and Maria N, (2014). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*. Issue: Technical Considerations for Maize Flour and Corn Meal Fortification in Public Health. Ann. N.Y. Acad. Sci. ISSN 0077-8923
- Rashad A. S, Kurt A. R and Carl J. B, (2013). Effects of Deterioration Parameters on Storage of Maize: A Review. *Journal of Natural Sciences Research* www.iiste.org ISSN 2224-3186 (Paper) ISSN 2225-0921 3 (9)

- Ray B., Sid T., Michael M. and Ali A., (2013). Grain Storage Systems Design. Handbook of Farm, Dairy and Food Machinery Engineering. DOI: <http://dx.doi.org/10.1016/B978-0-12-385881-8.00007-0>
- Sekeumade A.B and Oluwataya I.B. (2009). Comparative Analysis of Maize Storage Technologies in Kwara State, Nigeria. *Int. sustain prod.*4(5):24-31
- Shafiur Rahman, (2007). Handbook of Food Preservation. Second Edition. CRC Press Taylor & Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742
- Shaista Q., Muhammad A., Fahrulzaman H. and Muhammad A., (2017). Comparative Study for the Determination of Nutritional Composition in Commercial and Noncommercial maize flours. *Pak. J. Bot.*, 49(2): 519-523, 2017.
- Smith Erin , Charles Benbrook and Donal R. Davis. (2012). With the Grain: A closer look at the nutrient quality of grain, grain-based products, and the role of organic agriculture. The Organic Centre. www.organic-centre.org
- Sylvanus D. P. Odjo , Paul K. Malumba , Yves Beckers , François Béra, (2015). Impact of drying and heat treatment on the feeding value of corn. A review. *Biotechnol. Agron. Soc. Environ.* 2015 19(3), 301-312
- USDA, United State Department of Agriculture (2017). Cameroon Corn Production by Year (1000MT). [Index Mundi. https://www.indexmundi.com/agriculture/?country=cm...corn&graph=production](https://www.indexmundi.com/agriculture/?country=cm...corn&graph=production). Chart and table showing historical data - Cameroon Corn Production by Year (1000 MT).
- Wright E.J. , Webb M.C. and. Highley E , (2003). Stored grain in Australia. Proceedings of the Australian Postharvest Technical Conference, Canberra, 25-27 June 2003. CSIRO Stored Grain Research Laboratory, Canberra
- Zubaida Y. Nadia S. Asba R and Arusa A. (2015). Postharvesting Techniques and Maintenance of Seed Quality. New Challenges in Seed Biology - Basic and Translational Research Driving Seed Technology. <http://dx.do>