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Effect of Brine fermented Pickling to Physicochemical, Anti-nutritional, and Microbiological Attributes of Pickled gboma Eggplant (*Solanum macrocarpon*)

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Abstract

Gboma eggplant (*Solanum macrocarpon*) has low calorie, high phenolic and antioxidant, excellent dietary fibre and mineral content. Besides healthy effects, gboma eggplant also contained numerous anti-nutrients unbeneficial for human health. Due to high moisture content, gboma eggplant was highly perishable during post-harvest. This research observed the changes of nutritional proximate, mineral contents, acidification indexes, anti-nutrients, phytochemical and antioxidant properties, texture profiles, microbiological characteristics of both raw and pickled gboma eggplant. Gboma eggplant fruits were soaked in clean water for 2 minutes before cutting their calyx lobes. The pre-treated fruits were submerged in sterilized brine (5% salt) for 8 days. Periodically, pickled samples were taken to examine physicochemical, anti-nutritional, and microbiological attributes of pickled gboma eggplant. Results showed that nutritional proximate of moisture, ash, protein, fat, fibre, carbohydrate was varied slightly during fermentation. There was a decreasing trend of moisture and carbohydrate; meanwhile, there was an increasing trend of ash, protein, fibre during 8 days of fermentation. There was no significant difference of fat during pickling. There was a minor increment of mineral contents in all samples. There was accumulation of phenyllactic acid, ascorbic acid content and titratable acidity with exception of pH. Anti-nutrient contents like tannin, phytate, oxalate, steroidal glycoalkaloid greatly decreased in raw and pickled eggplant. Remarkable increments of total phenolic, flavonoid, DPPH free radical scavenging and FRAP ferric reducing antioxidant of raw and pickled eggplant was presented. Texture profiles of hardness, crispness, fracturability, crunchiness revealed a minor reduction of sensory scores during 8 days of fermentation. Lactic acid bacteria, *Bacillus* significantly proliferated; meanwhile, *Micrococcus* and *S. aureus* were absolutely retarded in pickled eggplant. Yeast and fungi increased in the first 4 days and decreased afterwards. There was no significant difference of proximate compositions; mineral contents; phenyllactic acid, ascorbic acid content, pH and titratable acidity; anti-nutritional contents; phytochemical and antioxidant properties; texture profile (sensory score); microbiological load (with exception of *S. aureus*) between pickled gloma eggplants at day 6th and day 8th of fermentation. At a quick glance, the length of fermentation could be shorted to 6 days instead of 8 days. However, at the 6th day, *S. aureus* load was still presented at 0.33±0.01 log CFU/g. The fermentation should be lasted to 8th day so that *S. aureus* load could be dropped down to zero to ensure microbial food safety. Raw gboma eggplant should be fermented in 8% brine solution for 8 days to obtain the best physicochemical, anti-nutritional, and microbiological properties of pickle. Findings of this research suggested that fermentation pickling would be an appropriate approach to improve nutritional, physicochemical and functional criteria while controlling toxic chemical residues, retarding the growth and proliferation of spoilage and pathogen microorganisms.

Keywords: Anti-nutrient, antioxidant, gboma eggplant, microorganism, nutritional proximate, phytochemical, pickling, texture profile

INTRODUCTION

Gboma eggplant (*Solanum macrocarpon*) is a common vegetable crop widely distributed in tropical and subtropical regions especially at high rainfall areas. The fruit included numerous seeds and it's partly filled by the calyx lobes.[1] It could be eaten raw, boiled, fried, stewed, or sauced. Gboma eggplant could be utilized for obesity prevention as well as limitation of numerous ailments.[2,3] Eggplant consisted of vitamin C and phenolic substances as potent antioxidants.[4] Excellent antioxidant capacity of gboma eggplant might be due to the excess amount of phenolic.[5] It effectively blocked tumor development and metastasis,[6] prevented inflammation, hypotensive and atherosclerosis.[7] Eggplant extract had excellent healing impact on various internal and external disorders.[8] It had a great potential in shooting superoxide free radicals and retardation of hydroxyl radical establishment via cross-blocking ferrous [3+].[6] Gboma eggplant with naturally fibrous skin created a defence mechanism against microbial invasion. Due to low calorie and high moisture content, gboma eggplant was very sensitive and perishable quickly under ambient conditions. Dehydration, postharvest disease and flesh browning were major quality deteriorations. Eggplant microstructure mostly included epithelial tissues. During pickling, dimension and image of the epithelial tissues were modified in the cell walls.[9]

Pickling was one of the oldest food preservation methods by either ways: (1) adding sugar for fermentation, (2) brine and or acetic acid for acidification. It involved extending shelf life of finished product under strong acidity, allowing its stability for years without freezing.[10] Pickling produced the finished product with desired taste, distinctive flavour and texture for long term consumption during off season. Lactic acid bacteria with probiotic properties improve self immune to contagious ailments in the gastrointestinal rout, against urogenital contamination, powerful cancer retardation, better metabolism, and lower triglyceride index in the serum.[11] Moderate consumption of pickled foodstuffs might cure muscle cramp of athletes through modification of electrolyte in plasma.[12] The fermentation naturally converted sugar to acid by lactic acid bacteria.[13] Brine contributed a key role in pickling by extracting moisture and substrate from plant which was available for lactic acid bacteria growth and proliferation. In order to obtain pickled products with acceptable physicochemical, anti-nutritional properties and microbial safety advantages, purpose of our study focused the changes of nutritional proximate, mineral contents, acidification indexes, anti-nutrients, phytochemical and antioxidant properties, texture profiles, microbiological characteristics of both raw and pickled gboma eggplant during 8 days of fermentation in 5% brine solution. Through pickling process, the added-value of raw gboma eggplant would be improved; consumers had more chance to use diversified food.

MATERIALS AND METHODS

Material

Gboma eggplant fruits were harvested in gardens of Binh Phuoc province, Vietnam. They were moved to laboratory quickly ready for experiments. Chemical reagents such as methylene blue, acetonitrile, methylene red, sulfuric acid, ammonia solution, ascorbic acid, potassium iodide, potassium persulphate, phenolphthalein, boric acid indicator, ethanol, methanol, aluminium chloride, sodium acetate, HCl, $FeCl_3.3H_2O$ were all analytical grade. Phenyllactic acid standard (> 98.0 % purity), sodium carbonate was obtained from Fluka (Switzerland). Folin-Ciocalteu phenol, trichloro-acetic acid, DPPH (2, 2-Diphenyl picrylhydrazyl) reagent, sodium nitrite (≥ 99.0 % purity), gallic acid and catechin reagents were purchased from Sigma Aldrich (USA). 3M-Petrifilm plates were purchased from Van Dai Phat Co. Ltd., Ho Chi Minh city, Vietnam.

Researching method

Gboma eggplant fruits were preliminarily washed under soaking with clean water for 2 minutes to separate dirt and soil. Sharp blade was used to cut their calyx lobes. The pre-treated fruits were then submerged in sterilized brine (5% salt) for 8 days. In 2 day-interval, samples were taken to determine nutritional proximate, mineral contents, acidification indexes, anti-nutrients, phytochemical and antioxidant properties, texture profiles, microbiological characteristics of both raw and pickled gboma eggplant.

Chemical compositions (moisture, ash, protein, fat, fibre, carbohydrate) were measured following the official method of analysis.[14]. Mineral compositions (Na, K, Ca, Mg, P, Fe, mg/100 g) were determined following Pearson protocol with flame photometer (Na, K) (Model: 1382, ESICO), atomic absorption spectrum (Ca, Mg, Fe) (model: PINAACLE900F, PerkinElmer) and spectrophotometer (P) (model UV-1800, Shimazu). Phenyllactic acid (mg/g) was determined by high-performance liquid chromatography or HPLC (model: HPLC 580, Techno) with ultraviolet detection.[15] Ascorbic acid content (mg/100 g) was measured by volumetric method using a 2,6-dichlorophenol indophenol visual titration method described by AOAC16. pH was measured with a pH meter (Hanna Instruments). Titratable acidity (mg lactic acid/100 g) was measured following the official method of analysis.[14] Tannin (mg/g) was determined following the method described by Adegunwa et al.[17] Phytate (mg/g) was measured by the method described by Wheeler and Ferrel.[18] Oxalate (mg/100g) was examined by the method described by Falade et al.[19] Steroidal glycoalkaloid (mg solamargine/kg) was determined by HPLC method described by Eanes et al.[20] (model: HPLC 580, Techno). Total phenolic content or TPC (mg GAE/100g) was estimated by Folin-Ciocalteu reagent assay.[21] Aluminium chloride colorimetric method was applied for quantification of total flavonoid content or TFC (mg QE/100 g).[22] DPPH free radical scavenging (mg TE/100 g) was estimated using UV-VIS

spectrophotometric method (model: UV5, Mettler Toledo) at wavelength 517 nm.[23] FRAP (mg TE/100 g) ferric reducing antioxidant was defined as power in reducing of Fe^{+3} to Fe^{+2} by an antioxidant using the method described by Benzie and Strain.[24] Texture profiles of hardness, crispness, fracturability, crunchiness based on 15-point scale were assessed by descriptive sensory analysis using the Spectrum™ method.[25] Panelists of 9 assessors (age 30-40 years old) were previously trained (90 hours) to utilize a 15-point strength ratio to evaluate hardness, crispness, crunchiness, fracturability in pickled products. During the training, panelists were individually evaluated to determine the overall panel mean and to ensure that all panelists were able to scale the properties of interest. Panelists were trained to rate hardness, crispness, crunchiness, fracturability based on reference samples proposed by the Spectrum™ protocol. Hardness was mentioned as the force necessary to compress the sample on first bite, with anchors between 0 (soft) and 15 (firm). Crispness was considered as the multiple, higher-pitched sounds emitted as the sample was crushed with the molar teeth. Crunchiness was described as a mono lower-toned noise released with each chew. Fracturability was elaborated as the strength in which the sample ruptures when bit down on between the molar teeth at a fast rate. Following training, panelists discussed together to an agreeing mark for each attribute of the pasteurized eggplant pickles, which were prepared directly from fermented eggplants and were provided as a reference sample. Reference pickles were stored at 4°C throughout the experiment and maintained their texture attributes, which were determined during the initial training of the panelists. Sensory evaluation. Samples analyzed for sensory evaluation were prepared in 2 oz. plastic cups specified with casual 3 digit numbers. All samples and the neutral pickle were prepared at ambient temperature accompanied by normal temperature distilled water, a 2 oz. sample of bread, and salt-free saltine biscuits to neutralize the palate between samples. Panelists were provided samples in a ordinary order to prevent prediction based on the order of sample display. Three to five pickle pieces were set in each sample cup. Panelists examined a set of 5 to 7 samples per session. They were also offered two 2 oz. sample cups specified as the neutral sample to calibrate scoring of taste and texture characteristics on the 15-point scale. Each panelist was guided to first taste the neutral sample, neutralize panelist's palate, and bite an unidentified pickle sample. Panelists were required to relax in two-minute interval between two samples to minimize tasting tiredness. They could either swallow or expectorate their samples. Three sensory replications were executed on each sample during the research. Sensory evaluation was performed on pickle samples, which were preserved at room temperature. The sensory profiling method was used during the sensory evaluation. Lactic acid bacteria or LAB (log CFU/g), *Bacillus* sp. (log CFU/g), *Micrococcus* (log CFU/g), *Staphylococcus aureus* (log CFU/g), yeast (log CFU/g) and filamentous fungi (log CFU/g) were enumerated by 3M-Petrifilm protocols.

Statistical analysis

The experiments were run in triplicate with different groups of samples. The data were presented as mean ± standard deviation. Statistical analysis was performed by the Statgraphics Centurion version XVI. The mean value and standard deviation of a set of data obtained by analysis of random samples estimating the population statistics. 95% of results would be expected to lie within the range $\bar{x}\pm 2s$ we described the lower and upper bounds of this range as the 95% confidence limits of the results. The differences between the pickling samples were analyzed using a one-way analysis of variance (ANOVA). A significant value was set at a 95% confidence interval ($P \leq 0.05$). . If significant differences were found, then post hoc analysis was performed using Duncan's multiple range tests.

RESULTS AND DISCUSSION

The proximate compositions of raw and pickled gboma eggplant were presented in Table 1. There was no significant difference of fat in pickling duration. Fermentation time had no significant difference on fat content. There was a declining trend of moisture and carbohydrate contents; an increasing trend of ash, protein, fibre in samples during 8 days of pickling. There was no significant difference of proximate compositions between pickled gloma eggplants at day 6^{th} and day 8^{th}. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. Our results

Table 1. Effect of fermentation time (days) to nutritional proximate (%) of raw and pickled eggplant

Fermentation time (days)	0	2	4	6	8
Moisture (%)	91.83±0.01^{a}	91.34±0.00^{ab}	90.76±0.03^{b}	90.15±0.02^{bc}	89.48±0.01^{c}
Ash (%)	0.82±0.00^{b}	0.83±0.02^{b}	0.87±0.01^{ab}	0.89±0.00^{a}	0.90±0.03^{a}
Protein (%)	1.05±0.03^{b}	1.07±0.01^{b}	1.13±0.00^{ab}	1.18±0.03^{a}	1.20±0.01^{a}
Fat (%)	0.42±0.02^{a}	0.41±0.03^{a}	0.42±0.02^{a}	0.40±0.01^{a}	0.43±0.00^{a}
Fibre (%)	2.46±0.00^{b}	2.49±0.01^{b}	2.53±0.00^{ab}	2.59±0.02^{a}	2.60±0.03^{a}
Carbohydrate (%)	4.07±0.03^{a}	4.00±0.02^{a}	3.89±0.01^{ab}	3.76±0.00^{b}	3.71±0.02^{b}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (c) represented the lowest value

Table 2. Effect of fermentation time (days) to mineral contents (mg/100 g) of raw and pickled

Fermentation time (days)	0	2	4	6	8
Na	2.78±0.02^{c}	2.85±0.01^{bc}	2.97±0.03^{b}	3.16±0.01^{ab}	3.35±0.03^{a}
K	125.81±1.29^{c}	129.45±1.16^{bc}	133.28±1.35^{b}	137.20±1.04^{ab}	142.53±1.22^{a}
Ca	8.19±0.01^{c}	8.30±0.02^{bc}	8.42±0.00^{b}	8.51±0.00a^{b}	8.67±0.02^{a}
Mg	14.67±0.02^{c}	14.98±0.00^{bc}	15.56±0.03^{b}	15.97±0.01^{ab}	16.43±0.00^{a}
P	23.74±0.18^{c}	24.03±0.13^{bc}	24.49±0.09^{b}	24.94±0.15^{ab}	24.61±0.12^{a}
Fe	0.23±0.03^{c}	0.28±0.01^{bc}	0.34±0.00^{b}	0.41±0.02^{ab}	0.49±0.03^{a}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (c) represented the lowest value

were similar to findings by Eletta et al.,[26] those of gboma eggplant (*S. macrocarpon*) were 92.00 ± 0.43, 0.80 ± 0.03, 0.52 ± 0.02, 0.15 ± 0.02, 2.50 ± 0.02 and 2.50 ± 0.02%, respectively. Similar data were mentioned on one study conducted by Agoreyo et al.[27] Fat content in gboma eggplant was quite low at 0.17 ± 0.01%.[3] High fibre and low-fat contents in gboma eggplant were ideal for minimizing over weight load, dysfunctions of constipation, carcinoma of the colon and rectum, diverticulitis and atherosclerosis.[28-30] The high fibre and low carbohydrate contents in gboma eggplant would be a positive signal for controlling of diabetes melitus.[31] The ash content in gboma eggplant was 0.47 ± 0.02 % by finding of Chinedu et al.[3] Carbohydrate content in gboma eggplant was reported at 4.42 ± 0.12 %.[3] One survey of Muhammad and Senay[32] reported that nutritional contents of eggplant consisted of carbohydrate (4.70- 5.88%), dietary fibre (2.80-3.40%), fat (0.18-0.20%), protein (0.80 - 1.01%). Abundant fibre in eggplant was useful for digestion by reducing toxic and harmful substances from stomach thus preventing stomach and colon cancer.[33] High carbohydrate, fit fibre and low protein contents induced eggplant to be an ideal ingredient for fermentation.[34] Variety of pickled products contained precious resources of vitamins, fibres, minerals, proteins, carbohydrates and lipids.[35-37] Abundant quantities of dietary fibres, vitamins and proteins were accumulated from pickling of garlic.[38]

Minerals were essential factors inevitable for human body. They played important role as co-factors for different physiological and metabolic pathways.[39] Mineral contents of raw and pickled gboma eggplant were presented in Table 2. There was an increasing trend of mineral contents from raw to pickled gboma eggplant during 8 days of pickling. There was no significant difference of mineral content between pickled gloma eggplants at day 6th and day 8th. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. One survey of Muhammad and Senay[33] reported that mineral contents of eggplant consisted of Ca (7.4 -9.0 mg/100 g), Fe (0.20-0.24 mg/ 100g), Mg (13.5 - 14 mg/100 g), Mn (0.20-0.25 mg/ 100 g), P (22.5 - 25 mg/ 100 g), K (129 - 130

Table 3. Effect of fermentation time (days) to phenyllactic acid (mg/g), ascorbic acid content (mg/100 g), pH and titratable acidity (mg lactic acid/100 g) of raw and pickled eggplant

Fermentation time (days)	0	2	4	6	8
Phenyllactic acid (mg/g)	7.31±0.04^{c}	8.65±0.03^{bc}	9.76±0.00^{b}	11.03±0.02^{ab}	12.46±0.01^{a}
Ascorbic acid (mg/100 g)	65.42±0.03^{c}	71.18±0.00^{bc}	83.50±0.01^{b}	96.15±0.04^{ab}	109.23±0.02^{a}
pH	6.79±0.01^{a}	5.13±0.02^{ab}	4.86±0.03^{b}	4.50±0.02^{bc}	4.12±0.00^{c}
Titratable acidity (mg lactic acid/100 g)	0.15±0.02^{c}	4.51±0.01^{b}	6.24±0.02^{ab}	7.69±0.03^{a}	7.81±0.03^{a}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (c) represented the lowest value.

Table 4. Effect of fermentation time (days) to anti-nutritional contents of raw and pickled eggplant

Fermentation time (days)	0	2	4	6	8
Tannin (mg/g)	65.14±1.05^{a}	31.06±0.63^{b}	24.35±0.58^{bc}	13.51±0.32^{c}	11.54±0.26^{c}
Phytate (mg/100 g)	126.53±3.41^{a}	81.45±2.75^{ab}	54.13±1.64^{b}	22.74±0.83^{bc}	9.37±0.35^{c}
Oxalate (mg/100g)	241.27±0.00^{a}	169.32±0.01^{ab}	97.46±0.02^{b}	31.25±0.01^{bc}	3.02±0.00^{c}
Steroidal glycoalkaloid (mg solamargine/kg)	49.62±0.03^{a}	31.53±0.02^{ab}	19.08±0.01^{b}	5.42±0.00^{bc}	0.86±0.02^{c}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (c) represented the lowest value.

mg/ 100 g), Zn (0.10-0.16 mg/100 g). According to findings by Kortei et al.[40] in analyzing bioactive constituents in raw gboma eggplant, mineral contents were noticed in range between 8.35±0.06 - 10.09±0.00 mg/kg for Fe, 29.58±0.12 - 30.83±0.02 mg/kg for Mg and 11.50±0.04 - 35.03±0.09 mg/kg for Na. Iron was a beneficial mineral participating in hemoglobin manufacturing and oxygenation of red blood cells, metabolism and circulation.[41] Magnesium was a key co-factor of various regulatory enzymes, participating in the power movement reaction.[42] It's related to enzymatic response of carbohydrate glycolysis. Its shortage might lead to chronic ailments. Sodium involved in the infusion of nerve impulses and kept an osmotic equilibrium of the cells in the living tissue.[40] Mg, Mn, P were important minerals for healthy bone. Fe was useful for teenagers, pregnant and lactating mothers.[43]

There was accumulation of phenyllactic acid, ascorbic acid content and titratable acidity with exception of pH during 8 days of pickling (Table 3). There was no significant difference of phenyllactic acid, ascorbic acid content, pH and titratable acidity between pickled gloma eggplants at day 6th and day 8th. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. Phenyllactic acid as an organic acid released from lactic acid bacteria effectively controlled proliferation of yeast and fungi.[15] Phenyllactic acid was presented in pickle products at trace amount.[44] It's believed as the main element responsible for antifungal property and extended stability.[45,46] Ascorbic acid content in eggplant berry was around 400–700 mg/kg.[47] Abundant vitamin C content in pickled foodstuffs might minimize benzene accumulation resulting to less cellular vulnerability.[48]

After washing and slicing, cut eggplant was immersed in brine to partly reduce fruit bitterness. Anti-nutrient contents like tannin, phytate, oxalate, steroidal glycoalkaloid greatly decreased in raw and pickled eggplant during 8 days of pickling (Table 4). There was no significant difference of anti-nutritional contents between pickled gloma eggplants at day 6th and day 8th. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. Tannin was structured as a hydroxyl group bonded to an aromatic ring.[49] Tannin had a powerful binding

capacity with proteins and minerals as well as non-specific enzyme inhibition. Tannin bound strictly with the –NH2 segments of peptides and proteins limiting their metabolism.[51] Tannin retarded α-amylase, trypsin and lipase resulting to lower metabolism of carbohydrates, proteins and lipids, respectively.[51-53] Moreover, tannin also combined with minerals leading to deficiency of micronutrients.[54] Tannin was mostly decomposed in gastrointestinal route by intestine microflora to release metabolites ready for absorption in blood; the remaining was discharged via manure.[55,56] Immersion in pickling process might reduce tannin content via diffusion mechanism. Phytate was salt form of phytic acid, myo-inositol hexakis dihydrogenphosphate. Phytate had negative charge therefore it easily bound with cation to create insoluble complex. Phytate chelated with amino acid resulting to deficiency of protein digestibility and bioavailability.[57] Phytate also interacted with carbohydrate via hydrogen bonding with a phosphate group limiting starch solubility and bioavailability.[58] Phytate was degraded in gastric and tiny gut by phosphatase. In gastric, phytate interacted with mineral to form mineral-phytate in dissolved status. In tiny gut, mineral-phytate began precipitated induced to low digestibility of mineral.[59] At colon segment, phytate was degraded by phytase originated from gastrointestinal microbiota. High content of Ca^{2+} and Mg^{2+} retarded the phytate dissolution and decomposition. Microbials in colon participated in phytate hydrolysis to lower phytate content in manure.[60] Phytate was mostly metabolized in tiny gut; a small amount was absorbed in blood.[59] Immersion in pickling process resulted to phytate lost through leaching and enzymatic hydrolysis.[61] 96% phytate in legume was decomposed in fermentation.[62] Oxalate had a strong ability to create insoluble particles via chelating different minerals, and vital micronutrients like iron, zinc and calcium.[63] In oral intake, oxalate constrained with minerals in the gastrointestinal route and limited their metabolism. Metabolism of oxalate happened in gastric, tiny colon and massive colon.[64] The huge gut was the main location for oxalate metabolism; soluble oxalate was metabolized via negative disperse.[65] Unavailable oxalate would be discharged in manure.[66] Soluble oxalate combined with calcium to turn into insoluble calcium oxalate, condensed in renal and urinary route, saturated into calcium oxalate crystals.[67] Oxalate oxidase, oxalate decarboxylase and oxalylCoA synthetase originated from microorganisms leading to oxalate reduction during pickling.[68,69] 74% reduction of oxalate content in cocoyam was noticed after fermentation.[70] Steroidal glycoalkaloid (solanidine) was believed as poisonous substance represented in gboma eggplant. It was N based substance including C27 basic skeleton and cholestane moiety in Solanaceae class. It's transformed by glycosylation of the alkamine steroidal skeleton at C-3b position.[71] This compound created a preventive mechanism against pathogen, pest, insect, herbivorous fauna and human.[72] Neurological symptoms and recession of the core mental chain were observed from consumption of raw gboma eggplant due to steroidal glycoalkaloid.[73] The existence of harmful steroidal glycoalkaloid inflicted diarrhoea, cancer and over condensation of calcium in cells.[74] Hence, steroidal glycoalkaloid should be eliminated to trace level through pickling.

During 8 days of picking, remarkable increments of total phenolic, flavonoid, DPPH free radical scavenging and FRAP ferric reducing

Table 5. Effect of fermentation time (days) to phytochemical and antioxidant properties of raw and pickled eggplant

Fermentation time (days)	0	2	4	6	8
TPC (mg GAE/100 g)	39.52 ± 0.18^{c}	45.26 ± 0.20^{bc}	49.31 ± 0.17^{b}	54.27 ± 0.26^{ab}	60.48 ± 0.13^{a}
TFC (mg QE/100 g)	23.39 ± 0.05^{c}	25.71 ± 0.11^{bc}	28.02 ± 0.08^{b}	31.15 ± 0.12^{ab}	36.20 ± 0.07^{a}
DPPH (mg TE/100 g)	27.94 ± 0.04^{c}	32.17 ± 0.03^{bc}	39.15 ± 0.05^{b}	44.24 ± 0.01^{ab}	51.04 ± 0.03^{a}
FRAP (mg TE/100 g)	14.82 ± 0.02^{c}	15.49 ± 0.01^{bc}	16.03 ± 0.03^{b}	16.85 ± 0.02^{ab}	17.31 ± 0.04^{a}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (c) represented the lowest value.

Table 6. Effect of fermentation time (days) to texture profile (sensory score) of raw and pickled eggplant

Fermentation time (days)	0	2	4	6	8
Hardness	12.05±0.04^{a}	11.86±0.01^{ab}	11.52±0.00^{b}	11.35±0.03^{bc}	11.18±0.02^{c}
Crispness	8.29±0.00^{a}	8.17±0.02^{ab}	8.05±0.03^{b}	7.96±0.04^{bc}	7.83±0.01^{c}
Fracturability	10.41±0.03^{a}	10.19±0.01^{ab}	10.03±0.02^{b}	9.87±0.01^{bc}	9.73±0.04^{c}
Crunchiness	7.93±0.02^{a}	7.84±0.03^{ab}	7.69±0.01^{b}	7.51±0.02^{bc}	7.38±0.00^{c}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (c) represented the lowest value.

antioxidant of raw and pickled eggplant were presented in Table 5. There was no significant difference of phytochemical and antioxidant properties between pickled gloma eggplants at day 6th and day 8th. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. Eggplant was ranked among top ten vegetables containing abundant phenolic and flavonoid substances with excellent antioxidant property.[75,77] They involved a promising conducive role on hyperlipidemia in animals[78] and a humble validity on hypercholesterolemia in humans.[79] Phenolics possessed numerous biological characteristics with powerful antioxidant activity against cancer and cardiovascular syndromes.[80] Flavonoids were highly evaluated as promising health-promoting components owing to their anti-oxidative, anti-cancer, and cardiovascular defend.[81] DPPH might be beneficial in limiting the degree of reactive nitrogen species in life cells.[82] The evaluation of antioxidant capacity to reduce iron reflected the power of one constituent to move an electron or hydrogen atom from another element to and an antioxidant capability to reduce the oxidized secondary substances in peroxidation.[83] Phytochemical constituents were beneficial in scavenging toxic free radicals in the body emitted by numerous biological tension and ailments.[84] According to findings of Eletta et al.,[26] raw gboma eggplant had a high DPPH scavenging activity with a low IC50 33.56 µg/ml. According to findings by Kortei et al.[40] in analyzing bioactive constituents in eggplant, total phenolic, flavonoid, DPPH, FRAP in raw gboma eggplant (*S. macrocarpon*) extract were in range 23.51±0.37 ±0.00 to 40.61±0.00 µL GAE/10 µL, 62.29±0.38 to 479.51±0.26 µL CE/10 µL, 18.79±2.92 to 60.93±13.42%, 0.023±0.00 to 0.092±0.00%, respectively. Lactic acid bacteria accompanied by fermented pickle biosynthesized vital vitamins.[85] Pickling facilitated to release plentiful functional elements (peptides and amino acids) and phytochemical antioxidants (phenols, flavonoids and sterols).[86] The increased of antioxidants via pickling could be due to the more accumulation of soluble solid substances. Moreover, the supplementation of sugar in the pickling step was proven to create favorable condition for the biosynthesis of reduced phenolics as well as prevention of the leakage of antioxidant components from the plant tissue.[87,88] Pickling effectively maintained and restored natural therapeutic substances and antioxidant properties of plants.[89] Phytochemical constituents in eggplant were useful to cell membranes and promote the memory ability of the cerebral by guarding its cell against brain tumor caused by free radical groups.[32]

Texture profiles of hardness, crispness, fracturability, crunchiness revealed a minor reduction of sensory scores during 8 days of fermentation (Table 6). There was no significant difference of texture profile (sensory score) between pickled gloma eggplants at day 6th and day 8th. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. Texture profiles of pickled eggplant were greatly affected by dimension and maturity of raw material as soluble dry matters involved into the fermentation process. Hardness was depicted as the strength needed to compact the pattern at first stung with anchors of 0 for tender to 15 for sturdy. Crispness was depicted at the more, higher peak sounds released as the pattern is mashed with the molar teeth. Fracturability was depicted as strength with which the pattern breaks when putting pattern between molars and stung down absolutely down at a quick speed. Crunchiness was depicted as a mono lower-toned sound to

Table 7. Effect of fermentation time (days) to microbiological load (log CFU/g) of raw and pickled eggplant

Fermentation time (days)	0	2	4	6	8
LAB (log CFU/g)	0.19±0.01^{e}	2.48±0.03^{d}	4.35±0.02^{c}	6.91±0.03^{b}	9.15±0.01^{a}
Bacillus sp. (log CFU/g)	0.31±0.02^{c}	1.94±0.01^{bc}	2.57±0.00^{b}	3.78±0.02^{ab}	4.63±0.00^{a}
Micrococcus sp. (log CFU/g)	2.05±0.03^{a}	1.41±0.02^{ab}	0.97±0.01^{b}	0.32±0.00^{bc}	0.09±0.02^{c}
S. aureus (log CFU/g)	0.92±0.01^{b}	1.28±0.00^{a}	1.05±0.02^{ab}	0.33±0.01^{c}	0.00±0.00^{d}
Yeast (log CFU/g)	0.27±0.02^{c}	0.58±0.03^{bc}	1.63±0.01^{a}	1.28±0.03^{ab}	0.91±0.01^{b}
Fungi (log CFU/g)	0.11±0.00^{c}	0.37±0.01^{bc}	1.42±0.00^{a}	1.09±0.02^{ab}	0.84±0.03^{b}

Figures are the mean of three replications ± standard deviation (n=3); Figures in row followed by the different letter/s (a, b, c, d, e) are differed significantly (α = P=0.05). Letter (a) represented the highest value while letter (e) represented the lowest value.

release mastication. Brine inhibited the activation of pectinolytic enzymes (polygalacturonase) that were responsible for softening of sample structure.[90] As a result of lactic fermentation, plant would have an extended stability, translucent image, and sturdy texture and pickle aroma.[89]

Brine affected to active microorganism and retarded softening of eggplant tissue. Brine supported for homofermentative lactic acid bacteria during pickling. It's very important to keep eggplant fully submerged in brine. In the present study, brine (5% salt) submerged eggplant for 8 days at ambient temperature. Lactic acid bacteria, *Bacillus* significantly proliferated; meanwhile, *Micrococcus* and *S. aureus* were absolutely retarded at in pickled eggplant. Yeast and fungi increased in the first 4 days and decreased afterwards (Table 7). There was no significant difference of microbiological load (with exception of *S. aureus*) between pickled gloma eggplants at day 6th and day 8th. Therefore, the length of fermentation could be shorted to 6 days instead of 8 days. *Lactobacillus* sp. was commonly encountered microorganisms involved in pickling of eggplant.[91] They were Gram [+], catalase [-], anaerobic, microaerophilic and aero-salt-sugar-tolerant in compulsory fermentative behavior.[92] Lactic acid derived from the natural fermentation retarded the growth and proliferation of spoilage and pathogen microorganisms.[93] Lactic acid bacteria (LAB) released heterogeneous flavour components, specific bacteriocins, and exclusive exopolysaccharides accounting for essential properties, like structure, flavour, and durability of the pickled products.[94] LAB also participated in detoxification and degeneration of mycotoxins to minimize potentially biological hazards. *Bacillus* sp. had stick-figure, Gram [+], catalase [+], compulsory aerobic or facultative anaerobic. *Bacillus* sp. was listed safely to create favourable condition for quick occupation of the healthy microbiota in the gastrointestinal routs, retardation of the assault and placement of intestinal pathogens and reduction of cholesterol.[95] Micrococcus belonged to Gram [+], aerobic, cocci, non-spore making, non-motile and [+] response to catalase, coagulase, deoxyribonuclease check.[96] *S. aureus* was foodborne pathogen isolated from home-made vegetable pickle.[97] Different yeast species such as *Candida, Saccharomyces, Schizosaccharomyces*, and *Torulopsis* etc were found in the fermented pickle.[98] Harmless yeasts proliferated on the surface and stabilized to the bottom.[10] Fungal species had an important role in pickling by producing lactic acid, fumaric acid and ethanol. They secured suitability and quality in the finished product.[99]

CONCLUSION

Eggplant was mostly cultivated for vegetable and medicinal goals. Raw gboma eggplant contained abundant nutritional, anti-nutritional and therapeutic components. Pickled eggplant had a distinctive sensory attributes and microbial safety benefits. During 8 days of fermentation, pickled eggplant had diversified nutritional proximate, low anti-nutritional contents, high phytochemical contents, desirable textural sensory characteristics and safe microbial indicators which were available for a healthy consumption. Raw gboma eggplant should be converted into pickled form as a functional food with nutritional and medicinal advantages for humans.

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DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

This article did not contain any studies with human participants or animals performed by the author.

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