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Research Article

Determination of the Functional Properties, Textural Quality and Surface Appearance of *Nyam NGUB*, a Plant-Based Food Manufactured from Wild Edible Terrestrial Orchids and Eaten in the North West and Western Regions of Cameroon as Meat

DOBGIMA John Fonmboh[1], Thierry NGANGMOU Noumo[1], FOKUNANG Charles Ntungwen[2,4]* and EJOH Richard ABA[1,3]*

[1]Department of Nutrition, Food and Bioresource Technology, College of Technology, The University of Bamenda Cameroon

[2]Department of Pharmaco-Toxicology and Pharmacokinetics, Faculty of Medicine and Biomedical Sciences, University of Yaoundé 1, Cameroon

[3]National School of Agro-Industrial Science, University of Ngaoundere, Ngaoundéré, Cameroon

[4]Laboratory for Preclinical Animal and Toxicology Research of the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé 1, Cameroon

***Corresponding Author:** FOKUNANG Charles Ntungwen, Department of Pharmaco-Toxicology and Pharmacokinetics, Faculty of Medicine and Biomedical Sciences and Laboratory for Preclinical Animal and Toxicology Research of the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé 1, Cameroon.

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Abstract

The wild edible terrestrial orchid tubers locally known as nyam NGUB in the grass field of Cameroon are a traditional processed food through an endogenous technique, that is eaten as a relish, meat snack, meat alternative, and/or meat replacement depending on the context in certain localities of the Western and North West Regions of Cameroon. The objective of this study was to characterize the product by its functional properties, texture, and colour.

Standard methods were used to determine the hydration potentials, bulk density, foam capacity, emulsion capacity, swelling potential, solubility, list gel concentration, syneresis, and freeze-thaw ability while texture profile analysis (TPA) was used for the hardness and the CIEL*a*b* method for the colour determination.

Results showed that the WAC and OAC were 2.62 ± 0.29 g/g and 0.46 ± 0.26g/g respectively while the solubility and swelling power were 1.97 ± 0.27g/g and 355.51 ± 14.24 % respectively. The capacity of the proteins to produce and maintain foam was 14.0 ± 1.0 % and 9.29 ± 0.06% after 30 minutes respectively. The ability of the powder to form a gel started from 0.05 ± 0.01g and the paste clarity at 620nm was 63.20 ± 2.0 nm. The extract of the powder could mix with oil to form an emulsion with a capacity of 1.47 and stability of 4.05 ± 0.07 at 500 nm. The freeze-thaw stability and syneresis were 5.9 ± 0.36 mL and 0.87 ± 0.52 mL respectively after 5 days. Texturally, the peak and final forces obtained during the compression of nyam NGUB were 1041.75 ± 18.95 N and 1021 ± 17.54N respectively which yielded hardness, adhessivity and viscoelasticity of 10.63 ± 1.90 N, 1041 ± 1.74 N.s and 3.33 ± 1.04 respectively. The colour difference (ΔE) of nyam NGUB was 62.45 ± 2.02 originating from white, red and yellow values of 28.23 ± 1.97, 1.12 ± 0.63 and -7.07 ± 0.81 respectively.

Nyam NGUB, though produced from tubers was considerably hard with a gelling capacity that generate sensitive chewiness with hydration properties that could serve not only as meat but in other products.

Keywords: Plant-Based Meat Alternative; Wild and/or Traditional Food; Functional Property; Hardness; Colour

Introduction

At least 1 in every 11 people suffered from hunger in 2023. This figure represents about 733 million people of the world's population [1]. In this regard, the UN has indicated that following this trend, about 582 million people will be chronically undernourished by 2030 and 50 % of the victims will be in Africa. Yet, the literature on vulnerability, food security and ecosystem services has insistently continued to emphasize cultivated foods [2]. This is a contributor to the close to 1.24 billion sub-Saharan Africans being the world's most food-insecure people despite being blessed with highly bio-diverse environments. The adoption of foreign structures and economic policies has contributed in weakening the survival strategies of the African communities [3] if not that of all low-resource settings. This is because the dominant developmental model subscribed to laboratory-generated knowledge, research stations, and Universities while indigenous knowledge systems remained greatly undervalued [4] despite the value, but often neglected and underutilized resources such as Wild Edible Plants (WEPs). Wild plants contain potential biomolecules both in organic and inorganic combinations. They are vital, inexpensive, and lucrative sources of vitamins, antioxidants, fiber, minerals, and other nutrients for many economically deprived natives. These plants have high nutraceutical value and are used for a wide range of ailments and have the potential to protect the human body from cancer, diabetes, inflammatory and cardiovascular diseases [5]. Amongst such underutilized, undervalued, and underestimated wild edible plants are terrestrial edible orchids.

Although all orchids are CITES Appendix II listed, ethnic groups in northeastern Zambia and the adjacent provinces in Tanzania, the Democratic Republic of Congo, and Malawi have records of chikanda and/ or kinaka consumption especially in times of famine or as a seasonal addition to dietary staples [6]. In Cameroon, napsie is consumed by the Bagam people of Galim in the Western Region [7] and certain localities of the North West Region consume nyam *NGUB* [8]. It is of interest to note that the South African chikanda and/ or kinaka as well as the Cameroonian napsie and nyam *NGUB* are all endogenously processed relish, snacks, and cakes consumed as meat substitutes that represent seasonal delicacies to these areas though not considered as basic staples. The wild terrestrial edible orchid tubers are collected during the period of affluence and processed tactfully into the desired meat loaf or cake like the chikanda or meat snack like *nyam NGUB*.

Since the technologically driven search for a convenient plant-based meat alternative still yields products that do not match the quality attributes of meat [9], rethinking the approach is orienting toward research being driven by product requirements and consumer needs, following ideas of reverse-engineering, or product-driven-process-synthesis is required [10]. Thus, it is imperative to explore other, more environmentally sustainable, sources of plant-based proteins oilseeds, nuts, algae, and cereals, pulse particularly are attractive due to its high protein content (19-43%) [11], cheap production cost, and resource efficiency. However, though traditionally textured products like tofu, tempeh, and seitan were not appreciated in Western countries [12], they at least paved the way for the emergence of new meat analogues. *Nyam NGUB* which is already being accepted by certain Indigenous people can also constitute a research focus but being a wild food, the food and the tubers lack technical data in literature, particularly the functional properties, texture, and colour. The main functional properties for meat analogue applications include solubility, gelation, water-holding capacity (WHC), oil-holding capacity (OHC) as well as emulsification and foaming properties which are highly relevant for a wide range of food applications, including baked goods, pastas, beverages, and dairy alternatives [13]. Obomeghei., *et al.* [14] indicated that the success of utilizing food ingredients in food manufacture depends on their contributions to the overall beneficial qualities which they impact to the manufactured food and this depends to a large extent on the functional properties since they determine the suitability of the ingredient for the intended purpose. The functional properties of plant proteins are affected by several factors including intrinsic factors such as cultivar type, genotype, and conformation, extrinsic factors such as environmental conditions (pH, ionic strength, sugar content, etc.), and processing conditions (pressure and temperature, etc.). The aim of this study was to evaluate the functional and textural properties as well as the colour of *nyam NGUB*.

Methodology

Plant material acquisition

The wild orchid tubers were collected from Abong-Phen in Kedjom Ketingoh and its environs in the Tubah subdivision of Mezam Division in the North West Region of Cameroon. For maturity and proper tuber quality, the tubers were collected between September and November of the year 2023.

Sample preparation

Nyam NGUB was prepared by washing the tubers thoroughly with running tap water and allowing to drain. The tubers (100g) were then crushed into 3 mm and 7 mm diameters using a meat mincer (Hendi Food Service equipment, Steenoven 213911 TX Rhenen, item/kod: 210864, voltage: 230V/50Hz, serial number: 18100263, 2018). Water was added and mixed properly in a mixer (Russell Hobbs model: 25930, 220-2240V, 50/60 Hz, 1000W, 29119X0) after which wood-ash extract prepared from selected tree trunks was introduced and properly homogenized. The resulting marsh was allowed to mature at room temperature and a laboratory meat filler (Hendi Food Service Equipment, Steenoven, 21, 3911 TX Rhenen, item/kod: 282137, serial number: 181031100, 2018) was used to fill the mix in an artificial sausage casing. An electronic warm water bath was then set at ebullition and the packaged product was cooked for 40 minutes. The water bath was put off and the sausage casing and content cooled to room temperature. The cooked product was then dried at 45 ^{0}C for 4 days in an oven (Huanghua Faithfull desktop constant temperature; Model: WHL-25AB, 600W, 220V, 50Hz, SN:20210101120010). The dried sample was ground and sieved to obtain fine powders which were preserved for subsequent analysis with the fresh portion.

Functional properties

The functional properties of the powders of the powder of nyam *NGUB* wwere evaluated according previous studies as indicated by Nwokocha., *et al.* [15] and Nuwamanya., *et al.* [16].

Textural analysis

Texture parameters were measured using Lloyd Universal Tensile Testing Machine (LFRA texture analyser, Brookfield, England) fitted with a 0-1000 N load cell. The samples were tempered to 28 ± 2 °C and cut into uniform squares of 30 mm with a thickness of 10 mm prior to TPA measurement. The cuts were then placed on the stage of texturometer and the force-distance curve was obtained for a two-bite deformation cycle using an aluminium cylinder probe with 85 mm of diameter and employing a crossed speed of 50 mm/min, trigger 0.01 N and the samples compressed at 60 % of the initial thickness of to determine various textural attributes. Hardness was the peak force (N) during the first compression. Springiness was the baseline width of the second compression (cm). Adhesiveness was the maximum negative force of the first compression (N).

Color measurements

The surface appearance was measured by the CIEL*a*b* method using 3NH (High-quality colorimeter NH300, SN: 3001683, Chine) with an 8 mm aperture, a D65 illuminant, an LED blue light excitation lamp and Φ8 mm/d mm illuminating/viewing geometry and a silicon photoelectric diode detector colorimeter. By using a standard white ceramic plate, the device was calibrated. Three random measurements of colour indices were carried out from different locations on the sample. The L* represented the lightness of the sample, ranging from black (L* = 0) to white (L* = 100). The* is the red spectrum (positive a*) and green (negative a*) and b* indicate the yellow (positive b*) and blue (negative b*) of the samples. The value of the standard white plate was 99.73 for L*, -2.3 for a*, and 6.23 for b*, respectively, and the chromaticity was measured from three random locations in each patty sample.

Statistical analysis

The results obtained were analysed on Statgraphics, [(Centurion XVI, 2011). The means of triplicate analysis were subjected to a one-way ANOVA at p ≤ 0.05 and where there were significant differences, the means were separated by the Duncan Multiple Range test.

Results and Discussions

Functional properties

Food functionality refers to the properties of a food other than nutritional value which have a significant impact on the application and determines the use of the food material in different food items. The importance of the properties varies with the type of food products in which the protein is used [17]. It is an important functional trait in food such as sausages custards and dough [18]. Table 1 presents the functional properties of *nyam NGUB* powder.

Property	Value
WAC (g/g)	2.62 ± 0.29
OAC (g/g)	0.46 ± 0.26
Solubility power (g/g)	1.97 ± 0.27
Swelling power (%)	355.51 ± 14.24
Bulk density (g/mL)	0.80 ± 0.01
Foaming capacity (%)	14.0 ± 1.0
Foam stability$_{30mins}$ (%)	9.29 ± 0.06
List gel concentration (g)	0.05 ± 0.01
Paste clarity $_{(620\ nm)}$	63.20 ± 2.0
Freeze thaw stability (mL)	5.9 ± 0.36
Emulsion capacity $_{(500\ nm)}$	1.47 ± 0.00
Emulsion stability $_{(500\ nm)}$	4.05 ± 0.07
Syneresis (mL)	0.87 ± 0.52

Table 1: Functional properties of dried *nyam ngub* powder

Water-holding capacity (WHC) and oil-holding capacity (OHC) describe the maximum amounts of water and oil a protein can retain, respectively. WAC plays an important role in the food preparation process by influencing certain functional and sensory properties. Indeed, the work of has shown that the high carbohydrate content of flour is responsible for the high capacity of a food to absorb water. However, the water absorption capacity of foods could sometimes be attributed to the protein content since records hold that the polar amino acids in proteins have an affinity for water molecules [19]. As such, increased WHC can partly be associated with a decrease in the solubility of denatured protein and greater exposure to the proteins' hydrophobic core, respectively [20]. Sila and Malleshi, [21] explained that flours with high water absorption capacity are more hydrophilic. In this like, it is evident that carbohydrate and protein content cannot be the only determinants of the water absorption capacity of food flours. Therefore, the strong water absorption capacities of the flours of *nyam NGUB* could be explained by the low lipid content. Indeed, Nelson-Quartey., *et al.* [22], demonstrated that the presence of lipids in large quantities in flour reduces the binding capacity of water to particular substances, thereby limiting the water absorption capacity. The water absorption capacity plays a major role in dough formation. Strong water absorption capacities flour could find applications in the formulation of certain foods such as sausage, dough, processed cheese, and bakery products though it will be indicative of the addition of an optimal amount of water to the dough, thus improving its workability. In addition, the good water absorption capacity of flour could be useful in the manufacture of products where good viscosity is required like soups and sauces [23]. Also, during extrusion, the WHC influences the porosity and air cell size of TVPs [24]. Water holding capacity is desired in food processing systems since it improves yield and offers suitable organoleptic properties that make foods irreplaceable to consumers [25].

The ability of a food component to physically entrap oil through a complex capillary attraction mechanism is vital for a range of applications and contributes to improved flavour retention, consistency, and mouthfeel. The high oil absorption capacity of flours is indicative of the presence of polar amino acids [26]. The OAC is vital in the food industry since it improves mouthfeel, and preserves flavor, while in food formulations, oil improves flavour and gives the food a smooth texture. It is also important in the preservation of foods by preventing the development of oxidative rancidity [27].

WHC and OHC affect the texture and sensory properties of meat analogues differently. The level of WHC of a protein enhances the juiciness of the resulting product by retaining more water, while OHC has a role to play in the mouthfeel and texture. Unlike solubility, partial protein unfolding of plant proteins during denaturation can be employed to increase the WHC and OHC [28]. WHC and OHC are essential for some food applications, such as the syneresis of plant-based yogurts and the cookability and juiciness of plant-based meats. Plant proteins with good water and oil-holding capacities are often used as meat extenders or in plant-based meat analogs. The water and oil holding capacity depends on carbohydrate contents, particle size, amount of damages starch, the ratio of amylose to amylopectin in starch, and intra and inter-molecular forces [29].

Solubility refers to a protein's ability to dissolve in an aqueous solvent since the hydrophilic groups are exposed in the native stage to enhance the solubility though increased denaturation and aggregation lead to reduced solubility. The denaturation and aggregation often occurring during the wet extraction of commercial protein concentrates and isolates make the process less suitable for food applications [30]. Solubility is proof of interaction between the amorphous and crystalline regions and measure granule dispersion after cooking [31].

The high-water solubility indices (WSI) of the powder of *nyam NGUB* may be due to the breakage of starch granules and exposure of hydrophilic groups under the effect of the increase in temperature. Thus, the water solubility index is related to the amount of water-soluble molecules. Similarly, the rise in the water solubility index is associated with a high level of amyloidosis [32]. However, the water solubility index cannot be attributed solely to starch degradation. Proteins, total sugars, and crude fat could play an important role in this change in functional properties. In addition, the high solubility of flours would suggest that they are easier to digest; they could therefore be used as ingredients for example in infant formulae. This physico-functional characteristic plays an important role in the choice of flours to be used as thickeners in the food industry [33].

Swelling power is a measure of starch's ability to absorb water and swell, indicating the extent of associative forces within the granules, thus it reflects the degree of dissolution during the starch swelling procedure. The lower the swelling power, the greater the degree of associative forces in the granules [31]. The high swelling power of flours is proportional to higher amylopectin contents [34].

The bulk density of a material indicates the relative volume of packaging material impacting the storage, transport, marketing, and wet food processing industry. It also provides information on the porosity of the product that can affect the choice and design of a package. Bulk density is also important in determining material handling and application during processing in the food. The physical attribute that characterizes the mixing quality of a particular material is high bulk density but not convenient for packaging since more packaging materials are required [35]. Low bulk density is a desirable factor for flours in feed formulation, especially feeds with less demotion as well as a better application in the infant food industry [36].

The foaming capacity is characterized as the interfacial area that can be created by protein while foaming stability is related to the ability to remain stable under gravitational or mechanical efforts. The stability of the foam (SF) improves the texture, uniformity, and appearance of foods. It corresponds to a colloid of many bubbles of gas trapped in a liquid. The formation of foam and how stable the form is depends on the type and degree of protein denaturation, pH, viscosity, and processing methods [37]. Foam stability is important for foods such as ice cream, chantilly, mousses, and marshmallows, with respect to the shelf-life and appearance of the product, and must be maintained when subjected to process variations such as heating, mixing, and cutting [38]. In general, proteins that exhibit low foaming capacity show good stability and vice versa.

The lowest concentration of gelation is referred to as the minimum concentration of protein where gel remains in an inverted tube and is considered as an index of gelation ability [39]. Starch gelatinization correlates with thermal properties while the degree of gelatinization is associated with the moisture content [40]. The gel-consistency test is a rapid, simple, and sensitive clue of cold paste viscosity with which it correlates inversely. High-gel flour can be used to develop products in which a higher solid content per unit volume is required, such as special diet foods, and food formulations for children [41]. The higher the LGC of a product, the higher the ability to form a stable gel.

The transmittance (% T) of the gel depends mainly on the type of spectrophotometer, the concentration of starch, the temperature of the treatment, and the storage time. The clarity of gels is a very desirable property of starches used as thickeners in the food industries, as it directly influences the brightness and opacity of foods. The poor dough clarity of starches makes them suitable for use in sauces and thickened foods where low transparency is desired [42].

Cold preservation particularly freezing is a highly cost-effective method, not only in extending the shelf life of products but also maintaining their quality; as such freezing is a must-use method for the storing, transporting, and preserving of food products. Freezing inhibits microbial growth and enzymatic reactions while maximizing the retention of the original flavor as well as reducing the loss of nutrients during storage [43]. However, the concentration effect induced by freezing may result in the denaturation, segregation, and aggregation of proteins, since the effect alters the surface hydrophobicity of proteins. Besides, freezing can also increase the intramolecular and intermolecular disulfide bond exchange reactions, potentially changing the functional properties of proteins [44]. Prolonged freezing inevitably causes ice crystal growth and protein denaturation thereby destroying the edible qualities (WHC) and colour which affects the sensory experience and commercial value to consumers [43]. The repeated freeze-thawing cycles occurring through the processing of frozen products [45] due to the temperature fluctuations during the transportation and circulation of frozen foods can cause multiple freeze-thaw cycles.

Food emulsions are thermodynamically unstable complex systems that can separate into their watery and oily phase with time. Emulsifiers are surfactants that enhance the formation of emulsions and preserve stability over time. Food proteins from either animal or plant origin are amphiphilic molecules absorbable at the interface of the emulsion to stabilize the oil droplets and functional properties are principally oriented by the position and amount of amino acids in the polypeptide chain [46]. Oil-in-water emulsion systems are observed in a variety of natural and processed foods, such as milk, salad dressings, ice cream, or butter, among others [47].

The term syneresis was coined by Graham in 1864 to describe the separation of liquid from gelatine gel [48]. This term has been used since then to describe the undesired phenomenon where the liquid is expelled from a large number of solid products, such as jams, jellies, sauces, dairy products, surimi, tomato juice, and sauces, as well as meat and soybean products. Syneresis marks the upper limit of the liquid-holding capacity of foods.

TPA

The texture is an important quality of meat analogues [49]. Hardness is a measurement of how hard a product is and is determined by the maximum force of the initial compression. The resistance to a given deformation, characteristic of the hardness was measured and expressed in Newton (N). Table 1 shows the values of elements of the TPA test for *nyam NGUB* while figure 1 is the picture of the product on which the test was carried.

The peak and final force of compression for *nyam NGUB* were 1041.75 ± 185.95N and 1021 ± 170.54N respectively indicating homogeneity in the structure as the values are not significantly different. The hardness and adhesivity of nyam *NGUB* was 10.63 ± 1.90N and 10.41 ± 1.74N respectively. The hardness of homemade patties was 25.05 ± 4.32N and commercial based patties ranged from 5.14 ± 0.77-5.90 ± 1.25N while plant-based pork ranged from 5.51 ± 1.11 - 12.23 ± 1.91N [50]. Songang., *et al*. [51] reported hardness of 444.83 ± 19.75N for burgers while Bakhsh., *et al.* [52] obtained 66.17 ± 4.24N and adhessivity of 0.20 ± 0.00N.s for plant-based beef.

Sample	Peak force (N)	Final force(N)	Hardness(N)	Adhesivity (N.s)	Viscoelasticity
Nyam ngub	1041.75 ± 18. 95	1021 ± 17.54	10.63 ± 1.90	10.41 ± 1.74	3.35 ± 1.04

Table 2: TPA analysis of *nyam ngub* for a knife blade at 1mm/s.

Figure 1: Nyam NGUB in artificial sausage casing and sliced indicating hardness and sliceability.

Surface appearance

Food colour is the first attribute perceived by consumers which plays a vital role in final product acceptability, especially meat. Colour is one of the most important sensory attributes used to evaluate the quality of products and the first criterion consumers use to judge meat quality. The main coloration of plant-based proteins comes from an irreversible condensation reaction between the carbonyl groups of melanoidins and the amino groups of lysine and arginine which produces melanoidins on the furan backbone [53]. Table 3 presents the colour attributes of *nyam NGUB* as illustrated in figure 2.

L*	a*	b*	c*	h*	dE*
28.23 ± 1.97	1.12 ± 0.63	-7.07 ± -3.22	7.12 ± 0.81	278.99 ± 8.69	62.45 ± 2.02

Table 3: Evaluation of the surface colour nyam NGUB.

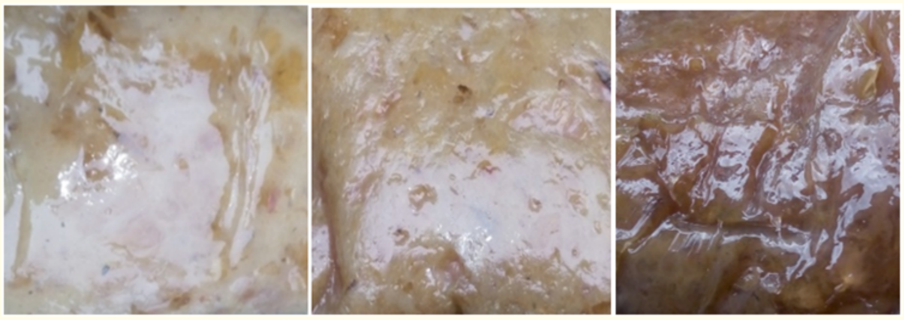

Figure 2: Nyam NGUB with different tubers showing possible colour traits.

The lightness (L of *nyam NGUB* (28.23 ± 1.97) was lower than those for burgers (46.73 ± 0.09) and patties (31.26 ± 0.35) reported by Songgang., *et al.* [51] and Bakhsh., *et al.* [52]. However, plant-based ports had l value of -61.53 ± 1.3. The redness (a*) and yellowness (b*) were respectively 1.12 ± 0.63 and -7.07 ± -3.22 as compared to 5.67 ± 0.27 and 35.63 ± 0.70 for burgers [51], 9.89 ± 1.50 and 14.69 ± 0.30 [54] and 11.1 ± 0.9 12.77 ± 0.15 for plant-based pork [52]. The chromaticity, ΔE for *nyam NGUB* was 62.45 ± 2.02 while that for the plant-based burger was (75.43 ± 0.95) [51]. The colour of samples is considered to be different when the value of the colour difference is 3.0 or more.

Conclusion

This paper aimed to determine and evaluate the functional and textural properties of *nyam NGUB* as well as the colour. The results showed that besides being eaten as a meat replacement/substitute/relish and/ or snack the powder of *nyam NGUB* had properties that were suited for the purpose on the one hand and on the other hand could have applications in the production of other products.

The relatively high WAC (2.62 ± 0.29g/g) of *nyam NGUB* could be useful in foods sausage, dough, processed cheese, and bakery products as well as products where good viscosity is required like soups and sauces or in food processing systems where yield improvement is required. The low OAC (0.46 ± 0.26g/g) indicates that polar amino acids are limited. Though *nyam NGUB* is not suitable as a meat extender considering the limited fat content, this is at least the basics to improve the mouth feel and preserve flavour. Since *nyam NGUB* is easy to digest due to its high solubility (1.97 ± 0.27g/g), it can serve as an ingredient in the infant food industry as well as a thickener in the food industry generally since the gel is bright (63.20 ± 2.0 at 650 nm). The structure of *nyam NGUB* was homogenous as the peak and final compression forces were not significantly different and required 1041.75 ± 185.95 N to compress the sample and this has made *nyam NGUB* very sliceable.

Nyam NGUB could thus be used as a product on its own or as an ingredient in other products based on the discovered qualities.

CRediT authorship contributions

Conceptualization: DJF, FCN and ERA and; methodology: DJF, TNN, FCN and ERA; formal analysis: DJF investigation: A.R., J.T. and C.C.; writing—original draft preparation: DJF; writing—review and editing: DJF, TNN, FCN and ERA. All authors have read and agreed to the published version of the manuscript.

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Data described in the manuscript, code book, and analytic code will be made available upon request pending approval.

Conflicts of Interest

The authors declare no conflict of interest.

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