IMPACT OF OKRA GUM ENCAPSULATION ON SOME PHYSICOCHEMICAL ATTRIBUTES OF YAM FLOUR

Uhiara S. Ngozi[1], Emmanel O. Samuel[1], Uhiara L.Nkoli[1], Okafor T. Dorothy[4] and Onuoha O. Gideon[1].

[1]Department of Food Science and Technology (FST) Federal Polytechnic Bauchi
[4]Department of Nutrition and Dietetics Federal Polytechnic Bauchi.

ABSTRACT: *Okra gum samples were prepared by two methods – The Conventional Method and by encapsulation. For encapsulation, okra gum solution made from 239.4g okra pod was thoroughly mixed with 303.4g of yam flour and then dried for 12 hours at 60^{o}C using cabinet dryer. The dried product (encapsulated gum) was marked – CG1. CG1 was repeatedly employed to cumulatively carry gum samples extracted from okra pods of known weights. This way, CG2 to CG5 were made. The weights and bulk densities of each of CG1 to CG5 were recorded. The viscosity, water holding capacity (WHC) as well as moisture content (MC) of CG5 was compared with those of pure okra gum and gum Arabic. Infrared spectroscopy was done on the pure okra gum at 0.5mm path. Results showed that the 303.4g yam flour, encapsulating gum extract from a total of 904.4g okra pod weighed 217g. In other results, pure gum, encapsulated gum and gum Arabic had 0.245, 0.317 and 1.22Nm^{-2} respectively for viscosity. For (WHC), they had 12, 12.60 and 16.00%., MC): 10, 7 and 46%. The infrared scan on pure okra gum showed strong C-CL stretching vibration, a difference from the work of other researchers.*

KEYWORDS: Okra Gum, Extraction, Composition Encapsulation, Commercialization.

INTRODUCTION

Gums have been broadly defined as hydrophilic or hydrophobic high molecular-weight compounds usually having colloidal properties that in an appropriate solvent or swelling agent produce gels, highly viscous suspension or solutions at low dry substance content (Handler, 1978). Substances meeting this definition and having application in food processing are hydrophilic plant or microbial polysaccharides or derivatives of such complex carbohydrates. Okra (*Abelmoschus esculentus*) gum was given 'GRAS' (Generally Recognized as Safe) status by American Food and Drug Agency (FDA) letters (FDA Bureau,2007).

Most published reports agree on the major components of okra gum – Two disaccharides 4-0-D galactopyranosyl-D-galactose and 2-0-(D-galactopyranosyluronic acid)-L-rhamnose. 2 Trisaccharides - D-galactopyranosyl-(D-galactopyranosyluronic acid)-L-rhamnose and (D-galactopyranosyluronic acid)-L-rhamnopyranosyl-D-galactose (Handler, 1978). The potential applications of okra gum include use as whipping agent for reconstituted dried egg white, an inhibitor to sucrose crystal formation, a component of adhesives, a difflocculant in paper or fabric production, a brightening agent in electroplating, and a component of a plasma replacement preparation (FDA, 2007). The nutritional importance of soluble and insoluble fiber which okra provides and can be made to provide even more in menus cannot be over emphasized. Yam (*Dioscorea rotundata*) is one of the staple food commodities that are widely accepted in Nigeria with growing global acceptability (Onwuka, 2014). It has unique properties

ISSN 2056-5798(Print), ISSN 2056-5801(online)

European Journal of Food Science and Technology
Vol.6, No.3, pp.1-8, August 2018
Published by European Centre for Research Training and Development UK (www.eajournals.org)

that enable them to tolerate a wide range of processing techniques, storage and final preparation (Ike and Inoni 2006).

The conventional method for extraction of okra gum for laboratory analysis consumes a lot of ethanol. Gum solutions would be washed (volume to volume) with 96% ethanol. The ethanol used is far more expensive than the gum produced. The method does not favor commercial production of okra gum. The study was aimed at adopting encapsulation as a cheaper technology for commercial production and presentation of okra gum. The specific objectives were (i) to extract okra gum and run infrared spectroscopy on it. (ii) to encapsulate yam flour with okra gum on cumulative as well as single treatment bases and compare some physico-chemical properties of products.

MATERIALS AND METHODS

There are three cultivars of okra commonly grown in Bauchi and environs-north-east of Nigeria. Kumatunakuya (matures in 40 days), yarrani (matures in 60 days) and yarcalawa (matures in 80 days). Based on works (Uhiara and Onwuka 2014; Uhiara *et al* 2018) which were on kumatunakuya, highlighting good protein efficiency ratio for the seed of kumatunakuya, the pods of the cultivar was acquired from the local farmers and adopted for this work , mainly to acquire more data on the variety.

Extraction and analysis of Okra Gums (pectin-like polysaccharides)

Employing the conventional method of gum extraction, the fruit pods of okra were sliced thinly ≤ 2mm. 0.5N Na_2CO_3 solution was added – enough to cover the slices of okra fruit. The mixture was stirred intermittently for 24 hours at pH 11 and room temperature (30^oC). The mixture was then filtered (1.25mm) and liquid extract stored in refrigerator at 5^oC. A second extraction was performed on the okra fruit material (filtrate), with half the quantity of water as in the first extraction. Yet a third extraction was carried out. The three liquid extracts were mixed into one. Its own volume of 96% ethanol was added onto it. The pectin-like polysaccharide – gum was precipitated and filtered out. The gum was dried under vacuum (-4kp) for 12 hours and sealed in a cellophane material (Amir, et al, 2011; Balami et al 2004).

Gum encapsulation*:* In this approach to okra gum production, yam flour was made to function as encapsulating agent or vehicle for okra gum. The yam flour (0.25 micrometer particle size) was produced by the method of Onwuka et al (2014).

Okra pods (239.4g) were sliced, 2-3mm thick and soaked in water (1.2w/v) for 24 hours. The (pods and water) mixture was then vigorously stirred with hand (wearing sanitary gloves) and sieved with muslin cloth. The gum solution recovered was thoroughly mixed with 303.4g of yam flour, and then dried for 12hours at 60^oC in a cabinet drier under air draft, yielding a product – CG1. Another batch of gum solution was made from 120g okra pod, mixed and dried with product CG1 at 60^oC, yielding product CG2. Yet another gum solution from 200g okra pod mixed and dried with CG2 yielded CG3. CG4 and CG5 were made with gum from 135g and 210g okra pod. Sample productions, as explained were done in duplicates, to among other reasons; enable withdrawal of portions for analysis. The weights and bulk densities of CG1 to CG5 were taken upon production. Bulk density (g /cm^3) = mass of gum/ volume (Balami et al 2004). This method which is a modification of the conventional method of Amir et al 2011, allows for the okra gum concentration of the encapsulating agent to be increased cumulatively

ISSN 2056-5798(Print), ISSN 2056-5801(online)

so that products could be presented at different (and higher) gum concentrations, without having to manage large quantities of pod and gum solutions in one batch. In a second and similar experiment another batch of gum solution was prepared from 239.4g okra pod. Sample gum solutions (4,5,6,7,8,9 and 10ml), were pippetted from the gum solution (second batch).The samples were each thoroughly mixed with 10g yam flour. They were dried for 12hours in a cabinet drier at 60^{o}C.Still in a third batch of experiment, different quantities (5, 10, 15, 20, 25 and 30)g of yam flour were weighed out, and each mixed with 10ml of okra gum solution pipetted from the gum solution from the second batch extraction, and dried for 12hours at 60^{o}C.

Employing the methods of Balami (2004) and Fenema (2003), viscosity (with falling sphere viscometer), water holding capacity as well as moisture content of the encapsulated gum from three experiments above were assayed comparatively with those of pure okra gum (extracted with ethanol) as well as Gum Arabic. The encapsulated gum samples CG1 and CG5, as well as 100% Yam flour, were reconstituted into 'fufu' (gelled, moldable and swallow able forms) by pouring 150ml of water (at 100 ^{0}C) into 100g of each of the sample, followed by rapid stirring with glass rod. The reconstituted samples were subjected to sensory evaluation, using a 20 man trained sensory evaluation panel.

Finally, Infrared spectroscopy was run on the pure Okra gum according to the method described by Mengshi, et al (2009) at 0.5mm light path.

RESULTS AND DISCUSSIONS

Weights of cumulatively encapsulated (303.49) yam flour

From work (section 2.1) on the conventional method of gum extraction, it was noted that from average of 35.7g Okra pod, 1g of gum could be extracted. The results of work on encapsulation indicated that as Okra gum was cumulatively added to the 303.4g of yam flour, the weight of the yam flour was rather decreasing. From table 1, the concentration of okra gum (after batch 1) in the (303.4g) yam flour would be (6.7/303.4 × 100) 2.21% (that is 239.4g of Okra pod would yield 239.4/35.7, or 6.7g gum). At the end of second batch, the concentration would have risen to (9.18/303.4 × 100) 3.02%. After the fifth batch, the concentration of okra gum in the (303.4g) yam flour would be as high as (20.18/303.4 × 100) 9.3%. Yet the respective weights of the 303.4g Yam flour were 252g, 233.1g and 221.5g. This pattern however became less significant after the fifth batch (Table 1). The above development resulted into total weight loss of 87.3g by the yam flour. The weight lost/g in the batches was respectively 10.54, 8.25, 2.50, 1.11, and 0.95. The total mass of gum employed was 20.18, while the total weight lost was 87.3g. This implies that the overall rate of weight lost was (87.3/20.18) 4.33/g gum.

In the second set of experiments, where fixed 10g yam flour was employed as vehicle for volumes of okra gum solutions (0.0, 10, 9.0, 8.0 7.0, 6.0, 5.0, 4.0 ml), weights after drying, became 9, 9, 9, 8.8, 9, 7, 8.3 and 8.8.g respectively. There was an average change (-1.2g), in weights of the yam flour. Still from the third set, where weight of flour was varied with okra gum solution fixed at 10mls, the weights changed to 5.2, 9.1, 13.8, 18.9, 22.9, and 28.1g, respectively from 5, 10, 15, 20, 25 and 30g i.e. average of 0.9g difference. The results of the three sets of experiments confirmed the phenomenon of 'apparent weight lost', in the entire

ISSN 2056-5798(Print), ISSN 2056-5801(online)

encapsulation operation It is possible there is some kind of chemical interaction between the gum and yam flour.

Results of Comparative Tests on Some Functional Properties of Okra Gum

From Table 2, pure gum had a moisture content of 10% while encapsulated gum had 5%. In solution, the encapsulated gum from second set of experiments was more viscous. None of these confirms serious disparity which an alteration in chemical structure could impact. In the course of the experiment, it was observed or noticed that this weight reduction tendency of the carrier of okra gum was more manifest at lower humidity, suggesting the production of volatiles (perhaps water) which escapes more readily at lower humidity. The above point brings up the issue of hydrophilic qualities associated with gums and hydrocolloids. It is possible that the highly hydrophilic gum is able to associate with and in the process makes water of hydration for example, available for evaporation.

Cumulative encapsulation ensures a decimal increase in the concentration of gum in the carrier/encapsulator, meaning decimal reduction of the concentration of the carrier itself. It creates room for the realization of product with up to 99.9% okra gum in subsequent batches. It creates room for a whole lot of products (0 to 99.99% okra gum), employable in food processing for desired gum or fiber levels. Encapsulation enhances the chances of commercial production of Okra gum (by not making use of ethanol), employing the cabinet drier.

This, techniques guarantee that a very dry product is derivable, an assurance of good shelve-life.

The bulk densities of the products decreased with their decreasing weights at higher okra gum concentrations (figure 1). The texture of the products looked finer (dustier) the more okra gum it carried, likely a reflection of the decreasing bulk densities.

CONCLUSIONS AND RECOMMENDATIONS

When sample CG was employed in batches for encapsulation of more okra gum, the concentration of yam flour will continue to decrease. This implies that if the process is continued, a batch will come where the concentration of yam flour will almost be zero. This technique continues to reduce decimally the quantity of the encapsulating flour from CG1 to CG5; all products with variable (gum) concentration, and retained or even improved viscosity, as well as shelf-stability. Also (table 3) there was no significant difference (particularly at lower concentrations of Okra gum) in texture, appearance and overall acceptability between Okra gum encapsulating Yam flour samples (CG1 and CG2), and 100% Yam flour ($P \leq 0.05$).

The infrared analysis apart from conforming with the general knowledge about okra gum further pointed to what could be an edge for okra gum – the presence of the –CL. (See fig. 2). This could provide room for interaction of okra gum with cations and cationic groups like Na^+(Fennema, 2004). Indigenous food, cosmetic and pharmaceutical firms should invest into mass production, and utilization as well as further study of the okra gum, it has great promises. Apart from areas of potential application mentioned under the introduction of this paper, encapsulated gum can function well as stabilizer in baked products, yoghurt, ice cream, soymilk, etc. (Zlatica, et al. 2009).

ISSN 2056-5798(Print), ISSN 2056-5801(online)

Table 1: Weights of cumulatively encapsulated (303.49) yam flour

Batches	Wt before Drying	Wt After Drying	Gum added(g)	Gum Conc. (%)	Bulk density
1	303.49^{a}	252.9^{c}	6.78^{a}	2.7^{c}	0.41^{d}
2	252.9^{a}	233.1^{c}	9.18^{a}	3.9^{c}	0.40^{d}
3	233.1^{b}	231.1^{d}	13.8^{b}	5.9^{d}	0.38^{e}
4	223.1^{b}	221.5^{d}	15.88^{b}	7.2^{d}	0.38^{e}
5	221.5^{b}	219.9^{d}	20.18^{b}	9.3^{d}	0.36^{e}

Values on same column with same letters are not significantly different ($p \leq 0.05$).

Wt = Weight.

Table 2: Results of Comparative Tests on Some Functional Properties of Okra Gum

Samples	Viscosity(NM^{-2})	Water HC (%)	Moisture Content (%)
Pure Gum	0.245	12	10
Encapsulated Gum (CG_5)	0.317	12.60	7
Gum Arabic	1.22	16.00	46

***water H C means water holding capacity.**

Table 3: Results of Sensory Evaluation

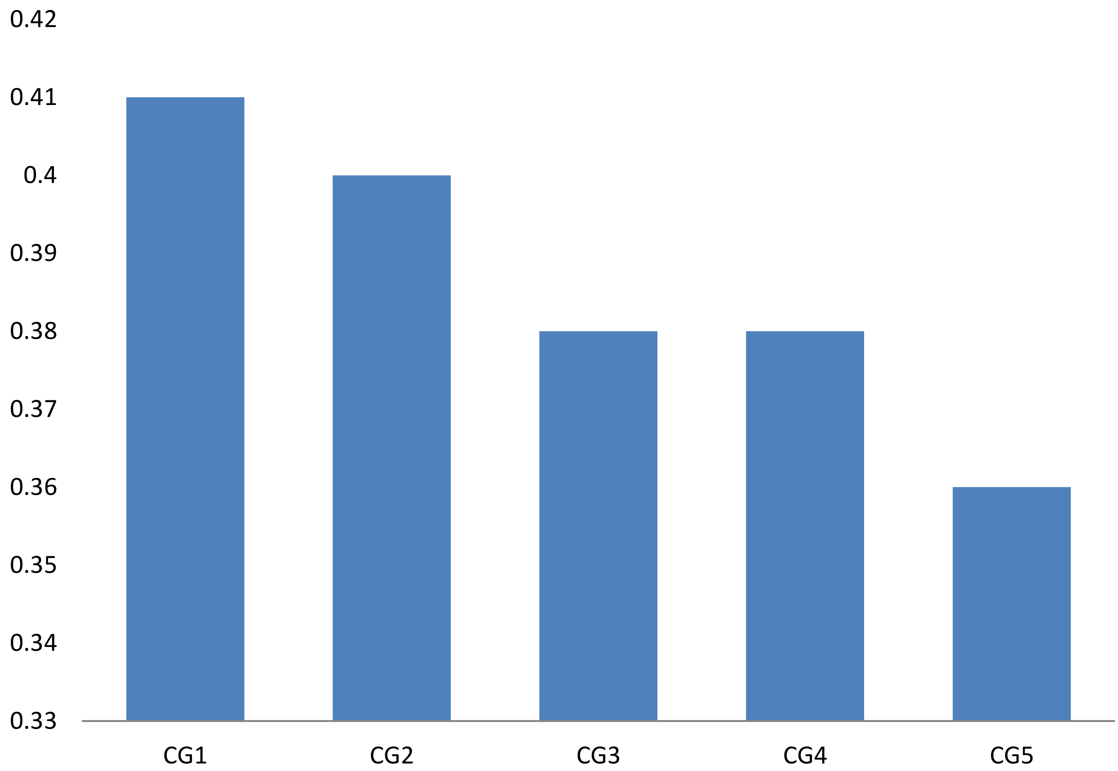
Samples	Colour	Appearance	Texture	Aroma	Overall acceptability
CG1	6.1±0.01^{a}	6.0±0.31^{b}	6.10±0.11^{c}	5.85±0.31^{e}	**6.0±0.10^{f}**
CG5	6.0±0.11^{a}	5.8±0.11^{b}	4.1±0.12^{d}	4.3±0.12^{f}	**4.1±0.22^{g}**
Pure Yam Floor	6.90±0.12^{a}	6.80±0.21^{b}	6.95±0.11^{c}	6.20±0.11^{e}	**6.20±0.13^{f}**

Mean ± SD with different superscript across columns are significantly different ($p \leq 0.05$)

CG1 = Yam flour (303.4g) encapsulating gum from239.4g Okra pod.

CG5 = Yam flour (303.4) encapsulating gum from a total of 904.4g Okra pod.

ISSN 2056-5798(Print), ISSN 2056-5801(online)



CGI = Product from batch1 (2.7% gum)

CG2 = Product from batch 2 (3.9% gum); CG3 (5.9%); CG4 (7.2 %); CG5 (9.3 %)

Figure 1: Bulk Densities of encapsulated Gum samples

ISSN 2056-5798(Print), ISSN 2056-5801(online)

Table 1: Result of infrared chromatography (Mengshilin and Rasco, 2009).

Wave Number (Range) (Micrometer)	Functional Group	Absorption Intensity	Vibration
2.7 – 2.9	-OH	Strong	O-H Stretching
3.1 – 3.6	-OH	Strong	O-H Stretching
5.65 – 5.81	Anhydride 2-, 3-unsaturated and aryl acyclic	Strong	Anhydride Stretching
6.67 and 6.9	Aromatic alkaline	Weak	C-C Multiple Bond Stretching
7.15 – 7.6	Tertiary alcohols and phenols	Strong	O-H, bending C-O Stretching
8.33 – 9.52	Sulphur Compound	Strong	C=S Stretching Vibration
10.05 – 10.15	Alkene monosubstituted (Vinyl)	Strong	C-H bending
11.3	Aromatic substitution one H atom	Strong	C-H bending
7.25 – 7.3	Alkane $-CH_3$	Weak	C-H bending
6.8 – 7.0	Alkane $-CH_3$	Weak	C-H bending
7.4 – 7.6	Aromatic Tertiary amine	Strong	C-N Stretching
12.5 – 16.6	Halogen	Strong	C-CL stretching

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