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Effects of Drying Methods on Physico-chemical Properties of Hydrocolloids Isolated from Peel Flour of Some Selected Root and Tuber Crops

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Authors' contributions

This work was carried out in collaboration among all authors. Author ANO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GIO and RMO managed the analyses of the study. Author RMO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Hydrocolloids isolated from the flour of peels of selected root and tuber crops were purified and their physicochemical properties were determined using standard procedures. The experimental material used was the peels of three species of *Dioscorea*: *alata* (water yam), *dumentorum* (trifoliate yam), *rotundata* (white yam) and *bulbifera* (aerial yam); *Colocasia esculenta* (cocoyam); white and yellow flesh of *Ipomoea batatas* (sweet potato). The fresh peels were dried under three drying method (oven, sun and air-dried). Proximate composition gave 4.4 to 10.7% for moisture content, 0.40 to 6.10% for ash content, 0.32 to 4.13% for crude fibre and in carbohydrates it ranges from 81.3 to 93.7%. There were no fat and protein in the experimental samples. Oven-dried *alata* peel flour gave the highest swelling index value 1.44% while, air-dried had the highest value of (4.00%) ranking the highest in foaming capacities. The highest in water and oil absorption capacities were sun-dried (2.05) *dumentorum* peel and *rotundata* peel air-dried (2.21). In emulsifying capacity and freezing-thawing stability, the highest results were observed in *colocasia*

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peel oven-dried (54.3%) and white flesh *Ipomoea batatas* peel sun-dried (74.3%). Yellow flesh *Ipomoea batatas* (0.31 g/ml) gave the lowest in bulk density. Gelation temperature ranges from 70 to 83ºC with pH of 6.6 to 7.6.

Keywords: Physicochemical; root and tuber crops; hydrocolloids; flour; peels.

1. INTRODUCTION

Root and tuber crops are grown in Nigeria and sub-Sahara Africa, it forms a major part of the staple food consumed by the people. Root crops are the edible energy-rich underground plant structure developed from modified roots while tuber crops edible carbohydrate-rich storage organs are developed wholly or partly from underground stems [1]. Peels are generated during the processing of tubers such as cassava, sweet potato, cocoyam and yam into different added-value products, and also the consumption of the tubers.

Tuber peels are mostly generated at the consumption level through the household, chop bars, food vendors etc. Peel losses are considerable high in some cases, for instance, yam peels constitute about 14% of the volume of yam consumed, bulbifera having the highest peel lost [2].

Tuber peels are being used currently to add value to waste by turning it into profit-making ventures [3] while peels from sweet potato have been used as a source of dietary fibre in bread making [4]. Tuber crops production has steadily increased to the tunes of 688 metric tons in 2001 to 740 million in 2007 [5]. Peels from the tubers could become a viable panacea to poverty alleviation in the developing countries [6].

Food gums that are complex carbohydrate derived from plants sources [7], that are water-soluble are hydrocolloids; hydro means water, while colloids mean dispersion of small particles in another medium [8]. They help give many of the food we eat their characteristic shape or consistency (IFAC, 2014). This study evaluates the physicochemical properties of the hydrocolloids isolated from selected root and tuber crops peels flour.

2. MATERIALS AND METHODS

2.1 Sources of Raw Materials

White and yellow flesh sweet potato (*Ipomoea batatas*), two species of yam (*Dioscorea rotundata* and *Dioscore aalata*) and cocoyam (*Colocasia esculenta)* were purchased from Ubani market Umuahia, while *Dioscorea dumentorum* was purchased from Orien-Ntigha in Isi-alaNgwa North of Abia State. The aerial yam (*Dioscorea bulbifera*) was purchased from the Abakiliki main market in Ebonyi State.

2.2 Sample Preparation of the Fresh Tubers

Each of the tuber samples (Sweetpotato, yams and cocoyam) was washed, peeled and chopped into smaller units of about 5-6 cm long [9]. The peels and flesh were divided into three (3) portions each. Each of the three portions was dried to constant weight using sun, air and oven drying method respectively.

Sun-drying: A portion of the various tuber samples (fresh and peels) were kept in the sun between 9 am to 4.30pm daily and were dried to constant weight for four (4) days.

Air drying (Room temperature): The second portion of each flesh and peels samples were placed in spread platform in an airy room to shed the samples from sunray. These were dried to constant weight for 8 days.

Oven drying: The third portion of each flesh and peels tuber samples were placed in an electrothermal oven (model; DHG) and dried to constant weight at 65^{o}C for 48 hours.

2.3 Flour Processing

The chips of fresh sweet potato, yams and cocoyam flesh and peel samples that were the sun, air and oven-dried to a constant weight respectively were milled into a fine powder using Thomas Willey mill and Binatone blender model BLG-401. Each of the samples flour was obtained from the fine powder by sieving with 150 μm aperture sieve. They were placed in a plastic bag and stored in an air-tight plastic container.

2.4 Defatting of the Flesh and Peels Flour (Cold Method)

The peels and fresh flour samples were defatted as described by Size-Tao and Sathe (2004). The flour samples were soaked with n-hexane to the ratio of 1:10 (w/v) for 24 hours. It was then filtered using filter paper and the residue (defatted samples) obtained.

2.5 Extraction and Purification of the Defatted Flour Samples

The extraction and purification were done by the methods of Oladipo and Nwokocha [10]; Onwueluzo et al. [11]. 120 g of fresh and peels of the defatted samples were dispersed in 800 ml of distilled water in 1000 ml beaker and the supernatant was decanted. The content left in the beaker was passed through a muslin cloth. Each of the residues was reconstituted with 500 ml distilled water and sieved again with a muslin cloth. Excess cold 99.9% ethanol was added to the residue. The precipitate formed was collected as a residue when the content in the beaker was filtered using a muslin cloth. The crude hydrocolloids was scooped into 500 ml beaker using a tablespoon. The crude extract was purified by dissolving in distilled water, homogenized and gradually precipitated with twenty (20) percent Ammonium sulphate and then washed with distilled water. The residue after washing was placed in 500 ml beaker and precipitated with excess cold 99.9% ethanol. This procedure was done severally until the washing was negative to the biuret test. The precipitate extracts were dewatered and were oven-dried at 65°C for 48 hours.

2.6 Analysis of the Isolated Purified Hydrocolloids

2.6.1 Proximate composition

Proximate composition (moisture, crude fibre, ash, crude protein, fat) was determined using standard methods described by the Association of Official Analytical Chemistry [12]. The percentage of carbohydrate was estimated by difference [13,14].

2.6.2 Functional properties

The swelling index was determined as described by the method of Iwuoha [15]. Bulk density was determined as described by Nep and Conwey [16]. Aqueous solubility was done by the method as described by Nwanekezi et al. [17]. Gelatinization temperature (GT), emulsification capacity (EC), oil and water capacity (OAC/WAC), foaming capacity (FC) and pH measurement were determined by the method as described by G.I., Onwuka [18].

2.7 Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA). Means were separated using Duncan's multiple range tests (DMRT) using the statistical package for social science (SPSS) version 17.0 (SPSS Inc., Chicago, IL, USA).

3. RESULTS AND DISCUSSION

Proximate composition of the isolated purified hydrocolloids.

The proximate compositions of the purified hydrocolloids are shown in Table 1. Moisture contents of the hydrocolloids were all below 10%, which suggests a reduction in the growth of microorganisms thereby increased in shelf life [19] and these are favourable to food processors and producers. The moisture content ranged from 4.40 to 10.7% with *Colocasia esculenta* peel air-dried (4.40%) ranking the lowest. In the peel samples, *builbifera* peel air-dried (6.10%) ranked the highest in ash content, having no significant differences ($p<0.05$) with *dumentorum* peel air-dried (5.425%), the lowest were in White fresh sweet potato peel sun-dried (0.400%). The ash contents were higher than purified locust bean gum (2.06%) (Sidley, 2013) and cashew gum (1.2%) [20, 21]. *Dumentorum* peel air-dried (4.130%) ranked the highest in crude fibre content, the resulting values recorded are comparable with cashew gum (4.8%) [20]. Gelatin (2.56%) [22] and *Delonix regia* food gums (0.37%) [18]. while *Colocasia esculenta* peel air-dried ranked the highest in carbohydrates (93.7%). There were no fat and protein contents after their determination. These portray thorough defatting during processing and complete removal of protein content during the purification process of the extracted hydrocolloids.

Table 2 shows the functional properties of the purified extracted hydrocolloids. *Alata* peel oven-dried (1.441) ranked the highest in the swelling index, while *Colocasia esculenta* peel air-dried (1.005) was the lowest. Ikegwu et al. [23] that fat and protein content of food gum effluences their swelling index, thus the result of the swelling

Table 1. Proximate composition of the tuber peels hydrocolloids samples

Sample names		Moisture (%)	Ash (%)	Crude fibre (%)	Carbohydrates (%)	Fat (%)	Crude protein (%)
dumetorum peel	oven drying	10.7^{a}	3.23^{f}	4.13^{a}	82.0^{f}	-	-
	Sun drying	10.0^{a}	4.85^{d}	3.87^{b}	81.3^{f}	-	-
	Air drying	9.79^{ab}	5.43^{b}	2.25^{d}	82.3^{f}	-	-
bulbifera peel	oven drying	8.11^{c}	5.05^{c}	1.55^{h}	85.3^{de}	-	-
	Sun drying	8.61^{c}	3.30^{f}	1.04^{i}	87.0^{d}	-	-
	Air drying	7.90^{c}	6.10^{a}	0.88^{k}	85.1^{e}	-	-
rotundata peel	oven drying	8.91^{bc}	1.73^{a}	0.43^{lm}	88.9^{cd}	-	-
	Sun drying	10.1^{a}	1.22^{h}	0.32^{n}	88.3^{d}	-	-
	Air drying	8.34^{c}	1.54^{g}	0.43^{lm}	89.7^{cd}	-	-
alata peel	oven drying	5.31^{efg}	3.56^{e}	0.46^{j}	90.7^{bc}	-	-
	Sun drying	5.47^{defg}	1.18^{h}	0.32^{n}	93.0^{a}	-	-
	Air drying	5.50^{defg}	3.15^{f}	0.37^{mn}	91.0^{b}	-	-
Colocasia esculenta peel	oven drying	4.62^{efg}	1.05^{hi}	0.81^{k}	93.5^{a}	-	-
	Sun drying	5.08^{efg}	0.90^{lj}	0.81^{l}	93.3^{a}	-	-
	Air drying	4.40^{efg}	1.09^{hi}	0.85^{kl}	93.7^{a}	-	-
White peel *sweetpotato flesh*	oven drying	6.14^{de}	0.60^{k}	2.51^{c}	90.8^{bc}	-	-
	Sun drying	5.68^{def}	0.40^{k}	2.50^{c}	91.417^{b}	-	-
	Air drying	6.58^{d}	0.50^{k}	2.513^{c}	90.407^{bc}	-	-
Yellow peel *sweetpotato flesh*	oven drying	5.66^{def}	0.90^{ij}	2.312^{e}	91.124^{b}	-	-
	Sun drying	5.99^{de}	0.82^{J}	2.100^{g}	91.096^{b}	-	-
	Air drying	6.13^{de}	0.94^{iJ}	2.215^{f}	90.713^{bc}	-	-
LSD		.063	.058	.006	.051	-	-

Samples mean with the same superscript down the columns are not significantly different (p<0.05)

Table 2. Functional properties of the isolated hydrocolloids samples

Sample names		S.I	FC (%)	Sol (%)	OAC	WAC	EC (%)	FTS (%)	D_B (g/ml)
dumetorum peel	oven drying	1.057^{cdef}	4.00^{a}	67.5^{e}	1.205^{fg}	1.505^{bc}	47.7^{f}	73.1^{b}	0.455^{ef}
	Sun drying	1.027^{ef}	3.85^{a}	66.7^{fg}	2.050^{ab}	2.050^{a}	47.7^{f}	72.0^{c}	0.456^{ef}
	Air drying	1.050^{cdef}	4.00^{a}	65.2^{i}	1.305^{ef}	1.050^{e}	48.8^{d}	73.0^{b}	0.462^{e}
bulbifera peel	oven drying	1.035^{def}	0.201^{d}	67.5^{e}	1.705^{c}	1.605^{b}	46.9^{g}	74.2^{a}	0.452^{f}
	Sun drying	1.029^{ef}	0.150^{d}	66.5^{gh}	1.605^{cd}	2.050^{a}	46.8^{g}	65.8^{g}	0.454^{ef}
	Air drying	1.235^{bc}	0.200^{d}	66.0^{hi}	1.905^{b}	1.050^{e}	47.8^{f}	65.8^{g}	0.452^{f}
rotundata peel	oven drying	1.057^{cdef}	1.900^{b}	51.6^{k}	1.405^{def}	1.305^{cd}	43.9^{j}	68.6^{ef}	0.375^{g}
	Sun drying	1.057^{cdef}	1.900^{b}	50.1^{l}	1.500^{de}	1.401^{bcd}	43.7^{j}	68.6^{ef}	0.331^{h}
	Air drying	1.309^{ab}	1.900^{b}	51.1^{k}	2.205^{a}	1.550^{b}	45.3^{h}	69.6^{d}	0.332^{h}
alata peel	oven drying	1.441^{a}	2.105^{b}	70.6^{ab}	1.410^{def}	1.305^{cd}	37.7^{L}	68.5^{ef}	0.456^{ef}
	Sun drying	1.105^{cdef}	2.000^{b}	61.5^{j}	1.305^{ef}	1.200^{de}	36.5^{m}	68.5^{ef}	0.456^{ef}
	Air drying	1.215^{bcd}	2.000^{b}	65.5^{hi}	1.300^{ef}	1.205^{de}	37.660^{l}	68.5^{f}	0.457^{ef}
Colocasia esculenta peel	oven drying	1.050^{cdef}	2.000^{b}	70.9^{a}	1.055^{g}	1.305^{cd}	52.3^{b}	68.8^{ef}	0.484^{cd}
	Sun drying	1.095^{cdef}	2.000^{b}	70.3^{b}	1.025^{g}	1.200^{de}	51.3^{c}	68.2^{ef}	0.486^{cd}
	Air drying	1.005^{ef}	2.000^{b}	69.2^{c}	1.045^{g}	1.300^{cd}	54.3^{a}	69.3^{de}	0.481^{d}
White peel *sweetpotato flesh*	oven drying	1.205^{bcde}	0.230^{d}	67.2^{ef}	1.305^{ef}	1.400^{bcd}	44.9^{i}	74.3^{a}	0.501^{b}
	Sun drying	1.211^{bcde}	0.215^{d}	67.2^{ef}	1.305^{ef}	1.400^{bcd}	44.9^{i}	74.3^{a}	0.510^{a}
	Air drying	1.211^{bcde}	0.210^{d}	67.0^{efg}	1.301^{ef}	1.400^{bcd}	45.9^{h}	74.2^{a}	0.491^{c}
Yellow peel *sweetpotato flesh*	oven drying	1.057^{cdef}	1.230^{c}	68.5^{d}	1.450^{de}	1.600^{b}	40.5^{k}	73.2^{b}	0.309^{i}
	Sun drying	1.110^{cdef}	1.230^{c}	68.5^{d}	1.300^{ef}	1.505^{b}	40.5^{k}	72.6^{bc}	0.310^{i}
	Air drying	1.105^{cdef}	1.230^{c}	68.9^{cd}	1.455^{de}	1.555^{b}	40.5^{k}	72.5^{bc}	0.309^{i}
LSD		.050	.051	.055	.504	.053	.073	.052	.058

Samples mean with the same superscript down the columns are not significantly different. ($p<0.05$)

Table 3. Gelation temperature and pH of the isolated hydrocolloids samples

Samples code		Gelation temperature (^oC)	pH
D. dumetorum	oven drying	70.0	7.0
	Sun drying	70.0	7.0
	Air drying	70.0	7.1
D. bulbifera	oven drying	80.0	7.5
	Sun drying	79.0	7.3
	Air drying	80.0	7.6
D. rotundata	oven drying	81.5	7.2
	Sun drying	80.0	7.1
	Air drying	80.0	7.1
D. alata	oven drying	83.0	6.6
	Sun drying	83.0	6.6
	Air drying	82.0	6.7
Colocasia esculenta	oven drying	75.5	6.8
	Sun drying	75.0	6.8
	Air drying	75.0	6.8
White flesh *Ipomoea batatas*	oven drying	82.0	6.9
	Sun drying	82.0	6.9
	Air drying	82.0	6.9
Yellow flesh *Ipomoea batates*	oven drying	80.0	7.0
	Sun drying	80.0	7.0
	Air drying	80.0	7.0

index could be due to no protein and fat in the hydrocolloids samples. However, the result was higher than the swelling index obtained in purified cashew gum (0.5) [20]. In foaming capacities, *dumentorum* peel oven-dried (4.0%) and *dumentorum* peel air-dried (4.000%) ranked the highest in values having no significant differences (P<0.05) with *dumentorum* peel sun-dried (3.85%). *Colocasia esculenta* peel (70.9%) ranked the highest in the percentage solubility values recorded having no significant differences with *alata* peel oven-dried (70.6%). In oil absorption capacities (OAC), *rotundata* peel air-dried (2.21) recorded the highest with the lowest in *Colocasia esculenta* peel sun-dried (1.03). While in water absorption capacities(WAC), *dumentorum* peel sun dried (2.050) and *builbifera* peel sun-dried (2.050) of the peel samples were the highest, *builbifera* peel air-dried (1.050) was the lowest. The results were higher than gum Arabic (0.280) and Bovine gelatin (0.00) in WAC, also higher than xanthan gum (1.28) gum Arabic (1.00) and Bovine gelatin (1.06) in OAC [22]. WAC and OAC are used in reducing syneresis and modifying the texture of foods, therefore, the extracted purified hydrocolloids from the peels of tuber crop can be applied in food formulation in this aspect. The highest emulsifying capacities of the peel samples were in *Colocasia esculenta* peel oven-dried (54.3%), the lowest was in *builbifera* flesh sun-dried (38.9%) and *alata* peel sun-dried (36.5%). There were significant differences (P<0.05) in freeze thawing stability of the peel samples respectively. White flesh sweet potato peel sun-dried (74.3%) ranked the highest in the peel samples, however there were no significant differences between White flesh sweet potato peel (74.2 to 74.3%) and in *builbifera* peel (74.3%). The results of the bulk density recorded showed White flesh sweet potato peel sun-dried (0.510 g/ml) ranked the highest and Yellow flesh sweet potato peel oven/air-dried (0.309 g/ml) the lowest. The results recorded may be attributed to the defatted tuber flours before extraction of the hydrocolloids which aid in the bulk density [24]. The highest value obtained in peels samples were higher than guar gum (0.474 g/ml) and diodea gum (0.504 g/ml) [25, 26], but lower than gum Arabic (0.61) [27]. Lower bulk density indicates higher porosity [28,29], thus, Yellow flesh sweet potato peel oven/air dried with the lowest bulk density will have high porosity compared with other peels samples.

Table 3. shows gelation temperature and pH measurement of the extracted purified hydrocolloids samples from the flour of peels experimental materials. The peels samples were 70ºC to 83ºC of gelation temperature with pH of 6.6 to 7.6 These were within the range of gellan gum gelation temperature of 65^oC to 83^oC [30]

and pH of Prosopis African gum of 6.8 to 7.1 [31]. This result showed that the extracted purified hydroc *bulbifera* olloids may be included in the group of gelling polysaccharide like carrageenan, pectin, agar, alginate [32] and also may be applied in the food industry for formulation of shape or structure generated at a certain temperature [33].

4. CONCLUSION

This study showed that hydrocolloid can be extracted from the selected tuber crops there were noticeable differences between the samples in the proximate composition, functional properties, gellation temperature and pH. The results as outlined in this work suggest the usefulness of this purified hydrocolloid in food design, manufacturing and formulation. Oven-dried and air-dried methods should be used in the drying of fresh tuber crops for extraction and purification of hydrocolloids. Hydrocolloids from *Colocasia esculenta* peel, Yellow flesh sweet potato peel White flesh sweetpotato peel, *rotundata* peel air dried, *bulbifera* peel air dried, *dumentorum* peel oven-dried that have very good qualities should be used both domestically and commercially for their specific functionalities. These hydrocolloids can replace some existing one and also increase the availability of hydrocolloids. These will aid in the reduction of post-harvest losses or waste of these tuber crops, and enhance sustainable development geared towards income generation for both farmers and consumers in Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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