https://dx.doi.org/10.4314/afsjg.v14i1.10

Effect of Blanching Period and Drying Temperature on Selected Physicochemical Properties of Cocoyam (*Xanthosoma sagittifolium*) Flour

***B. O. Oyefeso,[1] M. O. Ayorinde,[2] C. A. Ogunlade,[3] O. K. Fadele[4] and A. Akintola[2]**
* [1]Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria.
[2]Department of Agricultural and Bio-Environmental Engineering, Oyo State College of Agriculture and Technology, Igboora, Oyo State, Nigeria.
[3]Department of Agricultural Engineering, Adeleke University, Ede, Osun State, Nigeria.
[4]Department of Agricultural Engineering, Federal College of Forestry Mechanization, Afaka, Kaduna State, Nigeria.

*Corresponding Author: oyefesobabatunde@gmail.com

Received: 7th April 2021 Accepted: 17th November 2021

Abstract
This study investigated the influence of Blanching Time (BT) and Drying Temperature (DT) on some selected physico-chemical properties of cocoyam flour including water absorption capacity, bulk density, swelling index, wettability and gelatinization point. The quality parameters of the flour were analysed using AOAC standard methods and procedures. Two-factors, 3-levels Historical Data Design of Response Surface Methodology was adopted for the analysis to determine the effects of BT and DT on the investigated parameters. Second order polynomial model was obtained at 5% level of significance. The flour samples had 1.60 to 4.00% water absorption capacity, 0.71 to 0.81 g/cm^3 bulk density, 5.2 to 6.8 g/g swelling index, 7 to 16s wettability and 68 to 90 °C gelatinization point. Samples dried at 60°C and blanched for 9.05 mins had better quality with optimum response values of 3.37% water absorption capacity, 0.76 g/cm^3 bulk density, 6.22 g/g swelling index, 12.71 s wettability, and 85.73°C gelatinization temperature. BT and DT had significant effects on water absorption and wettability while no significant influence was observed on the bulk density, swelling index and gelatinization temperature of the flour at $p \leq 0.05$. These findings will serve as a guide in ensuring proper choice of blanching time and drying temperature based on end-use and desired physico-chemical properties of cocoyam flour.

Keywords: Cocoyam flour; Drying temperature; Physico-chemical properties; Pre-treatment.

Effet de la Période de Blanchiment et de la Température de Séchage Sur Certaines Propriétés Physico-chimiques de la Farine de Macabo (*Xanthosoma sagittifolium*)

Résumé
Cette étude a étudié l'influence du temps de blanchiment (BT) et de la température de séchage (DT) sur certaines propriétés physico-chimiques sélectionnées de la farine de macabo,

notamment la capacité d'absorption d'eau, la densité apparente, l'indice de gonflement, la mouillabilité et le point de gélatinisation. Les paramètres de qualité de la farine ont été analysés à l'aide de méthodes et de procédures standard de l'AOAC. La méthodologie de la conception des données historiques à deux facteurs et à 3 niveaux de la surface de réponse a été adoptée pour l'analyse afin de déterminer les effets de BT et DT sur les paramètres étudiés.Le modèle polynomial du deuxième ordre a été obtenu à un niveau de signification de 5%. Les échantillons de farine avaient une capacité d'absorption d'eau de 1,60 à 4,00 %, une densité apparente de 0,71 à 0,81 g/cm3, un indice de gonflement de 5,2 à 6,8 g/g, une mouillabilité de 7 à 16 s et un point de gélatinisation de 68 à 90 oC. Les échantillons séchés à 60 °C et blanchis pendant 9,05 minutes avaient une meilleure qualité avec des valeurs de réponse optimales de 3,37 % de capacité d'absorption d'eau, une densité apparente de 0,76 g/cm3, un indice de gonflement de 6,22 g/g, une mouillabilité de 12,71 s et une température de gélatinisation de 85,73 oC. BT et DT ont eu des effets significatifs sur l'absorption d'eau et la mouillabilité, tandis qu'aucune influence significative n'a été observée sur la densité apparente, l'indice de gonflement et la température de gélatinisation de la farine à $p \leq 0,05$. Ces résultats serviront de guide pour assurer le bon choix du temps de blanchiment et de la température de séchage en fonction de l'utilisation finale et des propriétés physico-chimiques souhaitées de la farine de macabo.

Mots-clés: Farine de macabo; Température de séchage; Pré-traitement; Propriétés physico-chimiques

Introduction

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott) is one of the most important members of root and tuber crops. It belongs to the genera of the family, *Araceae* (Ugwu 2009). It is mainly grown for its edible corms and cormels although its leaves are used for both medicinal and culinary purposes (Ikechukwu 2005, Falade and Okafor 2014). Cocoyam contains many nutrients such as carbohydrate, protein, vitamin C (ascorbic acid), vitamin E, thiamine, riboflavin, niacin, copper, fibre and essential amino acids in varying proportions depending on the variety and agronomic practices (Lewu *et al.* 2009).

Cocoyam is useful for various purposes including staple food in Africa and some other developing nations. It is used as soup or sauce thickener in some parts of Africa. The corms and cormels are usually consumed after boiling, frying or roasting and they can also be processed into flour. Cocoyam flour can be baked into snacks or formed into pellets for feeding livestock as concentrates. Cocoyam chips can be eaten with beans as a complete meal (Omueti *et al.* 2009). Starch from cocoyam cormels is also useful as ingredient for baby foods because the starch granules are small and easily digestible (Falade and Okafor 2014).

In its raw form, cocoyam has some antinutritional constituents such as calcium oxalate raphides, trypsin inhibitors, α-amylase inhibitors and sapotoxins which result in health complications, if not well processed (Falade and Okafor 2014; Owusu-Darko *et al*. 2014). However, the presence of some of these anti-nutritional factors can be reduced by processing operations such as peeling, grating, fermentation, drying, cooking, soaking and/or steeping the cormels in cold water overnight (Owusu-Darko *et al.* 2014; Raji and Oyefeso 2017).

Cocoyam, like other root and tuber crops, deteriorates few weeks after harvest due to many pre-harvest factors (such as diseases, pest infestation, genetic composition, environmental and cultural practices) and inadequate post-harvest technologies (FAO 1998; Raji and Oyefeso 2017) and this makes the crop scarce and expensive beyond the harvesting period. Processing of cocoyam into chips, flakes and flour with improved storage stability will extend its shelf life and thereby, make it available for use all year round. Cocoyam flour seems to be widely accepted by the populace among other products obtained from cocoyam cormel and drying is an important operation in the production of its flour. Other unit operations involved in its processing include washing, peeling, size reduction (cutting into required sizes and shapes), blanching, fermentation, milling and packaging. Drying is perhaps the oldest method of preserving food and agricultural materials which entails transfer of heat and mass (Maxwell and Zantoph 2002). It helps to reduce the moisture content of a product to a pre-determined level due to application of heat, with the attendant benefits of extending its shelf life, reducing the activities of deteriorating microorganisms, improving product quality, facilitating production of new products with unique characteristics and reducing storage losses (Sahay and Singy 1994; Mujumdar 1997).

Agricultural and food materials can be dried using various methods such as sun (open air), solar, oven, drum, tray or cabinet, microwave or flash drying among other forms of drying. According to Zantoph and Schuster (2004), sun drying uses heat from the sun and natural movement of the air which is the simplest and cheapest among the drying methods, although it exposes the food materials to environmental factors such as dust, bacterial growth and excessive respiration. Oven drying involves use of an enclosed equipment to reduce the moisture level in biomaterials. Solar drying involves the use of the sun's energy for drying but excludes an open air 'sun-drying'. It makes use of equipment called solar dryer which stores and harnesses the heat radiation from the sun to effect moisture removal from the product being dried. However, it has some problems related to being weather-dependent and timeliness of operation.

Blanching is essential prior to drying to prolong the lifespan by stopping enzymatic actions which causes loss of flavour, colour and texture. Blanching also removes some surface dirts, microbial load, entrapped gases and brightens colour and help reduce vitamin losses. Appropriate drying parameters such as thermodynamic properties of the drying air (temperature, relative humidity and velocity), product characteristics (size, shape and pre-treatment level) and drying methods can have significant effects on the quality attributes of the final products. This study therefore, investigated the effects of blanching time and drying temperature on some physico-chemical properties of cocoyam flour.

Materials and Methods

Sample preparation and pre-treatment

White-fleshed cocoyam cormels used for the study were purchased from *Gbonje* market in *Okeho*, Oyo State, Nigeria.

Fresh cocoyam cormels were washed thoroughly with clean water, peeled and cut into 3 mm thickness using a sharp stainless-steel knife. Sliced cormels were washed again to remove mucilage from the cut surfaces. The cocoyam slices were blanched in hot water at 60°C for 5, 10 and 15 minutes and oven-dried at 60, 70 and 80°C to investigate the effect of blanching time and drying temperature on quality attributes of the flour. Fresh and pre-treated cormels were openly sun-dried carefully. Sun drying was used as the control. The drying experiments continued until the samples were dried enough to break sharply between hands. Each dried sample was milled separately using a burr mill and sieved using a sieve mesh size of

500 µm to obtain the flour. The flour obtained was packed in air-tight polythene bags and labelled properly for further analysis.

Determination of physico-chemical properties

Water absorption capacity

Water absorption capacity is a very important parameter in mixing and it is expressed as mass of water absorbed per unit gram of flour sample. This was determined by mixing specific quantity of the flour with known quantity of distilled water and left at ambient temperature (30 ± 2 °C) for some time and centrifuged. Water absorption was found as the amount of water bound per gram of the flour. It was evaluated using Equation 1 (Chandra *et al.* 2015; Buckman *et al.* 2018).

$$W_a = \frac{M_{bw}}{M_{df}} \times 100 \qquad — 1$$

where:
W_a is water absorption capacity (%),
M_{bw} is mass of bound or absorbed water (g) and
M_{df} is mass of dry flour sample (g).

Bulk density

Bulk density was determined gravimetrically and calculated according to Equation 2. The bulk density of cocoyam flour was determined by filling it into a regular container of known volume. The mass of the flour in container was measured using a digital weighing scale.

$$\rho_b = \frac{M}{V} \qquad — 2$$

where: ρ_b is the bulk density (g/cm^3)
M is the mass of the sample (g) and
V is the packed volume of the sample (cm^3) obtained after repeatedly tapping its container.

Swelling index

Swelling index is the ratio of the swollen volume to the ordinary volume of a unit weight of the flour. This was determined by filling a graduated cylinder with the flour sample to a specific point. Some distilled water was added to the flour to a specific level and thoroughly mixed together. The swelling index was evaluated using Equation 3 (Buckman *et al.* 2018; Chandra *et al.* 2015).

$$S_i = \frac{M_{ws}}{M_{df}} \qquad — 3$$

Where:
S_i is swelling index (g/g)
M_{ws} is mass of wet sediment (g)
M_{df} is mass of dry flour sample (g)

Wettability

Wettability was determined as the amount of time taken for the flour sample to be completely wet and it was evaluated using Equation 4 according to Onwuka (2005).

$$W_o = T_w - T_d \qquad — 4$$

Where:
W_o is wettability (s),
T_w is total time taken for the flour sample to become completely wet(s) and
T_d is time at which the flour sample was discharged unto the water surface(s)

Gelatinization temperature

Gelatinization temperature was determined as the temperature at which the suspension from the flour began to form gel. This was carried out by applying the procedure described by Onwuka (2005) and Due *et al.* (2016). This involved suspending 10 g of flour sample in distilled water in a 250 cm^3 beaker and made up to 100 cm^3 flour suspension. The aqueous suspension was then heated in a boiling water bath, with continuous stirring using a stirrer. A thermometer was clamped on a retort stand with its bulb submerged in the suspension. The heating and stirring continued until the suspension began to gel and corresponding temperature was recorded 30 s after gelatinization was visually noticed.

Data analysis

All the data obtained were analysed statistically using Response Surface Method (RSM) to determine the effect of drying temperature and blanching time on the investigated physicochemical properties. The experimental design adopted was 2-factors, 3-levels Historical Data Design (HDD) of second order polynomial model and this was analyzed using Design Expert (Version 10). The data obtained were subjected to ANOVA (Analysis of Variance) test at 5% level of significance. The optimum values for both independent and response parameters were also derived. The relationship between these parameters were analysed and established.

Results and Discussion

The effects of blanching time and drying temperature on the water absorption, bulk density, swelling index, wettability and gelatinization temperature of cocoyam cormel flour were determined and presented in Table 1. ANOVA results on the selected physico-chemical properties of cocoyam flour are presented in Table 2.

Effect of blanching time and drying temperature on water absorption capacity

Water absorption capacity of the cocoyam flour had maximum and minimum values of 16% when sun-dried and 7% when blanched for 15 min, followed by oven drying at 80°C respectively. The optimum value obtained for the cocoyam flour was 3.37% at drying temperature and blanching time of 60°C and 9.05 min respectively. The variation in the drying temperature and blanching time significantly influenced water absorption response at $p \leq 0.05$ as shown in Table 2. Equation 5 represents the mathematical relationship between the water absorption and the independent variables (blanching time

Table 1. Effect of Drying Temperature and Blanching Time on Selected Physico-chemical properties of cocoyam flour

Drying Temperature (°C)	Blanching time (minutes)	Bulk density (g/cm^3)	Wettability (s)	Water Absorption Capacity (%)	Swelling Index (g/g)	Gelatinization Point (°C)
Fresh cormel	Nil	0.82 ± 0.015^{b}	16.00 ± 0.577^{a}	3.00 ± 0.057^{ab}	6.57 ± 0.024^{b}	90.00 ± 0.432^{a}
	5	0.73 ± 0.057^{ab}	12.00 ± 0.353^{ab}	3.00 ± 0.058^{ab}	6.00 ± 0.403^{a}	83.00 ± 1.155^{bc}
60	10	0.78 ± 0.019^{ab}	13.00 ± 0.577^{ab}	3.33 ± 0.115^{ab}	6.67 ± 0.375^{b}	86.00 ± 0.577^{ab}
	15	0.77 ± 0.027^{bc}	12.00 ± 0.318^{bc}	4.00 ± 0.289^{a}	6.21 ± 0.057^{b}	86.00 ± 1.000^{ab}
	5	0.76 ± 0.027^{ab}	11.00 ± 0.455^{ab}	1.50 ± 0.153^{b}	6.20 ± 0.431^{b}	85.00 ± 0.455^{ab}
70	10	0.78 ± 0.015^{ab}	12.00 ± 1.155^{bc}	2.33 ± 0.115^{ab}	6.20 ± 0.355^{b}	83.00 ± 1.155^{bc}
	15	0.76 ± 0.022^{bc}	12.00 ± 1.000^{de}	2.33 ± 0.115^{ab}	6.13 ± 0.338^{b}	86.00 ± 1.000^{ab}
	5	0.72 ± 0.021^{c}	8.00 ± 0.577^{d}	1.77 ± 0.100^{b}	6.66 ± 0.189^{b}	66.00 ± 0.577^{h}
80	10	0.71 ± 0.017^{c}	8.00 ± 0.299^{de}	1.68 ± 0.057^{b}	5.18 ± 0.519^{b}	76.00 ± 1.000^{fg}
	15	0.73 ± 0.003^{c}	7.00 ± 0.298^{e}	1.81 ± 0.029^{ab}	5.30 ± 0.443^{b}	76.00 ± 0.577^{fg}

Values with the same superscripts along the same columns are not significantly different at $p \leq 0.05$.

Table 2. ANOVA Results on Selected Physico-chemical Properties of Cocoyam Flour

Properties	Source	Sum of Squares	Df	Mean Square	F-Value	p-value
Water Absorption Capacity (%)	Model	5.7	5	1.14	20.09	0.0163
	A	4.28	1	4.28	75.54	0.0032
	B	0.58	1	0.58	10.28	0.0491
	AB	0.23	1	0.23	4.06	0.1372
	A^2	0.59	1	0.59	10.48	0.048
	B^2	0.00405	1	0,00405	0.071	0.8066
	Residual	0.17	3	0.057		
	Cor Total	5.87	8			
Bulk Density (g/cm^3)	Model	0.00474	5	0.00095	2.98	0.1987
	A	0.0024	1	0.0024	7.56	0.0708
	B	0.00042	1	0.000417	1.31	0.3351
	AB	0.00023	1	0.00023	0.71	0.4618
	A^2	0.00142	1	0.00142	4.48	0.1246
	B^2	0.00027	1	0.00027	0.86	0.4228
	Residual	0.00095	3	0.00032		
	Cor Total	0.00569	8			
Swelling Index (g/g)	Model	1.44	5	0.29	1.2	0.4684
	A	0.5	1	0.5	2.11	0.242
	B	0.25	1	0.25	1.04	0.3831
	AB	0.62	1	0.62	2.58	0.2065
	A^2	0.06	1	0.06	0.25	0.6504
	B^2	0.00889	1	0.00889	0.037	0.8593
	Residual	0.72	3	0.24		
	Cor Total	2.15	8			
Wettability (s)	Model	39.36	5	7.87	27.43	0.0104
	A	32.67	1	32.67	113.81	0.0018
	B	7.11E-15	1	7.11E-15	2.48E-14	1
	AB	0.25	1	0.25	0.87	0.4195
	A^2	5.56	1	5.56	19.35	0.0218
	B^2	0.89	1	0.89	3.1	0.1767
	Residual	0.86	3	0.29		
	Cor Total	40.22	8			
Gelatinization Point (°C)	Model	344.69	5	68.94	7.17	0.0679
	A	228.17	1	228.17	23.72	0.0165
	B	32.67	1	32.67	3.4	0.1626
	AB	12.25	1	12.25	1.27	0.3412
	A^2	68.06	1	68.06	7.07	0.0764
	B^2	3.56	1	3.56	0.37	0.5862
	Residual	28.86	3	9.62		
	Cor Total	373.56	8			

A=Blanching time (minutes), B=Drying temperature (°C) and drying temperature)

$$W_a = 30.54 - 0.80A + 0.434B - 0.0048AB + 0.00545A^2 - 0.000467B^2 \; (R^2 = 0.78) \quad — 5$$

Where:
W_a is water absorption capacity (%),
A is Blanching time (minutes) and
B is Drying temperature (°C).

The samples which were oven-dried at 80°C had higher absorption capacity than the other cocoyam flour samples. This could be attributed to the relatively higher drying temperature resulting in much lower equilibrium moisture content (Oyefeso *et al.,* 2021), thereby causing the flour samples to absorb more water. This is in line with the report by Hayta et al. (2006) which indicated that drying increased the absorption capacity of flour. According to Niba *et al.* (2001), water absorption capacity is an important physicochemical property which is of significance in baking applications as well as bulking and consistency of products. Figure 1 shows the relationship between the water absorption capacity of cocoyam flour and blanching time, with the drying temperature.

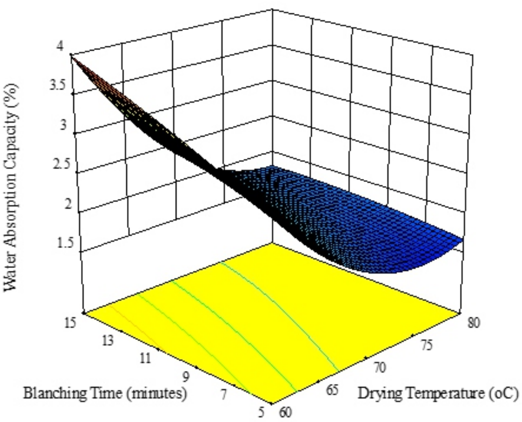

Fig. 1. Variation of water absorption with blanching time and drying temperature

Bulk density of cocoyam flour

Bulk density of the cocoyam flour ranged from 0.71 g/cm^3 at 80°C drying temperature and 10 min blanching time to 0.82 g/cm^3 for sun-dried samples without blanching. The optimum value obtained for the cocoyam flour was 0.74 g/cm^3 at drying temperature (60°C) and blanching time (9.05) min. The relationship between bulk density and the independent variables i.e., drying temperature and blanching time were found not to be significant ($p \leq 0.05$). Equation 6 represents the mathematical relationship between the bulk density and the independent variables.

$$\rho_b = 0.561 - 0.368A + 0.0251B - 0.000157AB + 0.000267A^2 - 0.000467B^2 \; (R^2 = 0.78) \quad — 6$$

Where:
ρ_b is bulk density (g/cm^3),
A is Blanching time (minutes) and
B is Drying temperature (°C).

The bulk density of cocoyam flour samples varied from 0.71 to 0.82 g/cm^3. Untreated cocoyam flour had the highest (0.82 g/cm^3) while sample oven-dried at 60°C and water blanched for 10 mins had the lowest (0.71 g/cm^3). Variations in the bulk density of the flour samples were significant ($p \leq 0.05$) for different blanching periods and drying temperature levels. The low bulk density of the oven-dried cocoyam flour samples could be attributed to low amount of moisture retained in them after drying. This finding is also supported by the report of Hayta *et al.* (2006) which indicated that drying decreases the bulk density of flour. Low bulk density of flour indicates that the products could be easily transported and distributed to required locations at reduced cost (Agunbiade and Sanni 2003). High bulk density of flour is an indication of a good mixing quality (Lewis 1990). Figure 2 shows the relationship between the bulk density of cocoyam flour and blanching time, with the drying temperature.

Swelling index of cocoyam flour

The swelling index of the cocoyam flour was found to have a maximum value of 6.67 g/g when blanched for 10 mins and oven dried at 60°C while it had a minimum value of 5.10 g/g when blanched for 10 mins and oven dried at 80°C. The optimum value obtained for the cocoyam flour was 6.22 g/g at 60°C drying temperature and 9.05 mins blanching time. The variation in process parameters i.e., drying temperature and blanching time did not significantly influence swelling index response ($p \leq 0.05$). Equation 7 represents the mathematical relationship between the swelling index and the independent variables. Figure 3 shows the relationship between the swelling index and blanching time with the drying temperature.

$$S_i = 5.15 + 0.292A + 0.456B - 0.00785AB + 0.00173A^2 + 0.00267B^2 \quad (R^2 = 0.67) \qquad — 7$$

Where:
S_i is swelling index (g/g),
A is Blanching time (mins) and
B is Drying temperature (°C).

The swelling index of cocoyam flour ranged from 5.18 to 6.57 g/g. Fresh sample had the highest value of 6.57 g/g while samples oven dried at 60°C with 5 mins blanching time had the lowest value of 5.18 g/g. Ojinaka et al. (2009) also reported that cocoyam samples had better swelling index when compared to flours from cassava and some other root crops. Swelling power of flour describes the degree of associative forces within the granules (Moorthy and Ramanujan 1986).

Wettability of cocoyam flour

The wettability of the cocoyam flour was found to have a maximum value of 16 s when sun dried while it had a minimum value of 7 s when blanched for 15 minutes and oven dried at 80°C. The optimum value obtained for the cocoyam flour was 12.71 s at 60°C drying temperature and 9.05 mins blanching time. The variation in drying temperature significantly influenced the time of wettability at $p \leq 0.05$. Equation 8 represents

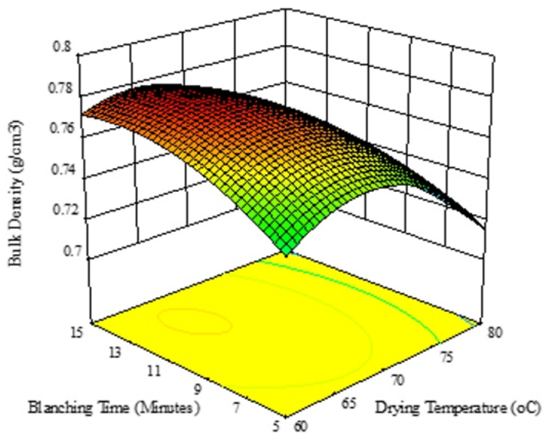

Fig. 2. Variation of bulk density with blanching time and drying temperature

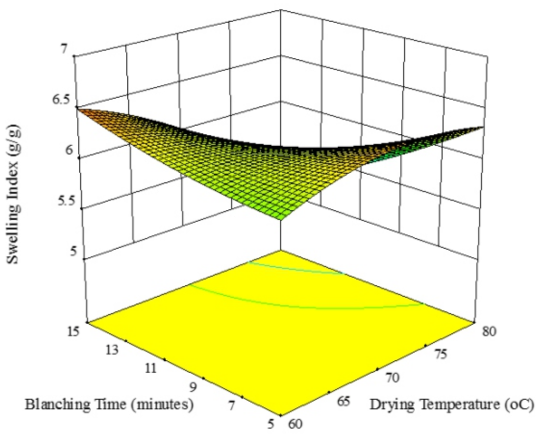

Fig. 3. Variation of swelling index with blanching time and drying temperature

the mathematical relationship between the wettability and the independent variables while Figure 4 shows the relationship between the wettability and blanching time with the drying temperature.

W_o = -59.39 + 2.15A - 0.88B - 0.005AB - 0.0167A^2 - 0.0267B^2 (R^2 = 0.98) — 8

W_o is wettability (s),
A is Blanching time (minutes) and
B is Drying temperature (°C).

Gelatinization temperature of cocoyam flour

The maximum gelatinization point of the cocoyam flour was 90°C when sun dried and a minimum of 80°C when blanched for 5 mins and oven dried at 80°C. The optimum value obtained for the cocoyam flour was 85.73°C at 60°C drying temperature and 9.05 minutes blanching time. The variation in drying temperature did not significantly affect gelatinization temperature ($p \leq 0.05$). Equation 9 represents the mathematical relationship between the gelatinization point and the independent variables while Figure 5 shows the graphical relationship between the wettability and blanching time with the drying temperature.

G_o = 142.61 + 7.20A - 0.917B + 0.035AB - 0.0583A^2 - 0.0533B^2 (R^2 = 0.92) — 9

Where:
G_o is gelatinization temperature (°C),
A is Blanching time (minutes) and
B is Drying temperature (°C).

The gelling temperatures obtained for cocoyam flour samples contradicts the values reported by Owuamanam et al. (2010). High gelling temperature obtained for cocoyam flour samples could be as a result of the presence of other nutritional components such as protein and lipid in the flour which could affect the swelling capacity of the flour and thus, increase the heat requirement for the flour to reach its final swelling (Jane *et al.*, 1999).

Conclusions

The effect of blanching time and drying temperature on the water absorption capacity,

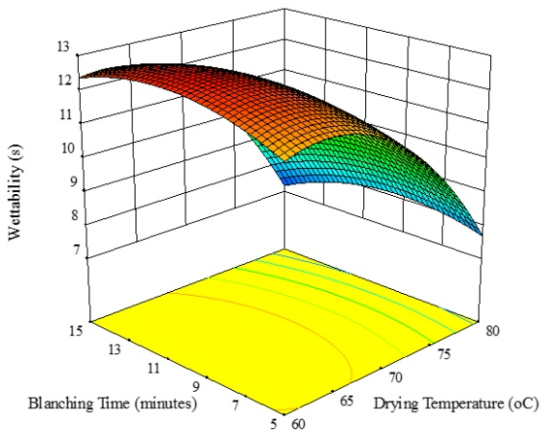

Fig. 4. Variation of wettability with blanching time and drying temperature

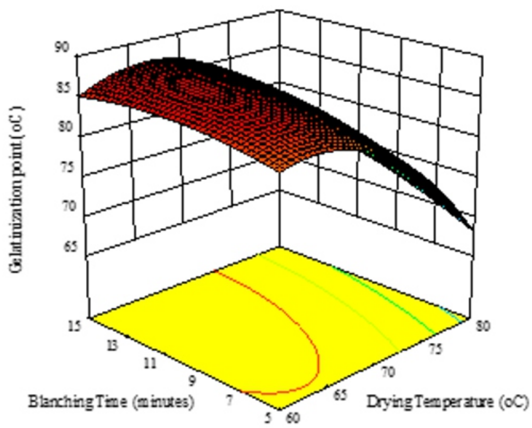

Fig. 5. Variation of gelatinization point with blanching time and drying temperature

bulk density, swelling index, wettability and gelatinization temperature of cocoyam cormel flour was investigated. Variation in the drying temperature and blanching time significantly influenced water absorption response and wettability while the blanching time and drying temperature had no significant influence on the bulk density, swelling index and gelatinization temperature of the flour at 95% level of confidence. The findings from this study will serve as a guide in ensuring proper choice of blanching time and drying temperature based on the end-use and the desired cocoyam flour properties.

Conflict of interest

The authors declare no conflict of interest concerning the study.

References

Agunbiade, S.O. & Sanni, M.O. 2003. The effect of ambient temperature of cassava tubers on starch quality. In: Root Crops - The small processor and development of local food industries for market economy. Proceedings of the Eight Triennials Symposium of the International Society for Tropical Root Crops. African Branch (ISTRC-AB) 12-14 Nov. IITA, Ibadan, Nigeria,pp 180-194.

Buckman, E.S., Oduro I., Plahar, W.A. & Tortoe, C. 2018. Determination of the chemical and functional properties of yam bean (*Pachyrhizus erosus* (L.) Urban) flour for food systems. *Food Science and Nutrition* 6(1):457–463. doi: 10.1002/fsn3.574

Chandra, S., Singh, S. and Kumari, D. 2015. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science Technology,* Vol.52(6): 3681–3688.

Due, E.A., Koffi, D.M. & Digbeu, Y.D. 2016.Physicochemical and functional properties of flour from the wild edible mushroom (*Termitomyces heimii* Natarajan) harvested in Côte d'Ivoire.*Turkish Journal of Agriculture, Food Science and Technology* 4(8): 651-655.

Falade, K.O. & Okafor, C.A. 2014. Physical, functional, and pasting properties of flours from corms of two Cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) cultivars. *Journal of Food Science and Technology* 52(6):3440-3448. doi:10.1007/s13197-014-1368-9

FAO, 1998. Storage and Processing of Roots and Tubers in the Tropics; The FAO Document Repository. Agro-industries and Post-Harvest Management Service. Agricultural Support Systems Division. Rome,Italy. http://www.fao.org/3/X5415E/x5415e00.htm# Accessed on 21 June, 2021.

Hayta. M., Alpaslan, M. & Bayer. A.D. 2006. Effect of drying on functional properties of Tarhana. *International Journal of Food Science and Technology* 29: 457-462.

Ikechukwu, G. 2005. Food analysis and Instrumentation: Theory and practice, Nigeria. Pp. 133-137.

Jane, J., Chen, Y.Y., Lee, L.F., McPherson, A.E., Wong, K.S., Radosavljevic, M, *et al.* 1999 Effects of amylopectin branchchain length and amylose content on the gelatinization andpasting properties of starch. *Cereal Chemistry* 76(5): 629-637.

Lewis, M.J. 1990. Physical Properties of Food and Food Processing Systems. 2nd Ed., Hartnolls Ltd., Bodmin, Cornwall.

Lewu, M.N., Adebola, P.O. & Afolayan, A.J. 2009. Effect of cooking on the proximate composition of the leaves of some accessions of *Colocasia esculenta* (L) Schott in Kwazulu-Natal province of South Africa. *African Journal of Biotechnology* 8(8): 1619-1622.

Maxwell, E.O. & Zantoph, U.B. 2002.Drying effect on food products. 4th ed., CBS publishers, New Delhi, India.

Moorthy, S.N. & Ramanujan, T. 1986. Variation in properties of starch in cassava varieties in relation to age of the crop. *Starch Starke* 38(2):58-61.

Mujumdar, A.S. 1997. Drying fundamentals. In Industrial Drying of Foods, ed. C. G. J. Baker, 7-30. London: Chapman & Hall.

Niba, L.L., Bokonga, M.M., Jackson, E.L., Schlimme, D.S., & Li, B.W. 2001. Physicochemical properties and starch granular characteristics of flour from various Manihot esculenta (cassava) genotypes. *Journal of Food Science* 67(5): 1701–1705. doi: 10.1111/j.1365-2621.2002.tb08709.x

Ojinaka, M.C., Akobundu, E.N.T. & Iwe M.O. 2009. Cocoyam starch modification effects on functional, sensory and cookies qualities. *Pakistan Journal of Nutrition* 8: 558-567.

Omueti, O., Otegbayo, B., Jaiyeola, O. & Afolabi, O. 2009. Functional properties of complementary diets developed from soybean (*Glycine max*), groundnut (*Arachis hypogea*) and crayfish (*Macrobrachium spp*.). *Electronic Journal of Environment, Agriculture, Food and Chemistry* 88:563-573.

Onwuka, G.I. 2005. Food Analysis and Instrumentation: Theory and Practice. Napthali Prints, Surulere, Lagos, Nigeria.

Owuamanam, C.I., Ihediohanma, N.C.& Nwanekezi, E.C. 2010. Sorption isotherm, particle size, chemical and physical properties of cocoyam corm flours. *Researcher* 2(8): 1-9.

Owusu-Darko, P.G., Paterson, A. & Omenyo, E.L. 2014. Cocoyam (corms and cormels)— an underexploited food and feed resource. Journal of Agriculture, Chemistry and Environment 3(1): 22-29.

Oyefeso, B.O., Akintola, A., Afolabi, M.G., Ogunlade, C.A., Fadele, O.K. & Odeniyi, O.M. 2021. Influence of moisture content and speed on cutting force and energy of tannia cormels. Research in Agricultural Engineering 67(3): 123-130.

Raji, A.O. & Oyefeso, B.O. 2017. Elasticity of cocoyam cormel as influenced by moisture content and loading orientation when in transit and storage. *Agricultural Engineering International: CIGR Journal* 19(4): 193–199.

Sahay, K.M. & Singy, K.K. 1994. Unit operations of agricultural processing. 1st ed. Vikas Publishing House Pvt. Ltd., India.

Ugwu, F.M. 2009 The potentials of roots and tubers as weaning foods. *Pakistan Journal of Nutrition* 8: 1701-1705.

Zantoph, B.C. & Schuster, U.N. 2004 Effect of solar drying on food products. *International Journal of Food Technology* 27: 323-329.