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OPTIMIZATION OF A CONVECTIVE DRYING PROCESS FOR PRODUCING STARCH-ALBUMEN POWDER AS COATING MATERIAL IN FRIED FOODS

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Abstract: Dried starch was added to egg albumen at concentration of 10-30% to increase solid matter content prior to convective air drying at 40-60°C with hot air velocity of 4.5 m/s. The functional properties of starch-albumen powder (SAP) and properties of the coated fried yam chips were fitted to response surface regression model. Our findings suggest that for a multiple objective of minimizing oil uptake and moisture content and, maximizing acceptability of fried chip drying at temperature of 40°C and starch content of 11.3% should be used.

Keywords: Tray drying, starch-albumen powder, optimization, response surface regression, functional properties

INTRODUCTION

Poultry egg is a highly perishable agricultural product and shows rapid quality deterioration within a maximum of two week when stored at room temperatures (Scott and Silversides, 2001) due to its high moisture and protein content favorable to microbial growth. Consequently, powdered form of poultry egg is preferred by food handlers and processors due to its greater stability, convenience in handling and use.

Egg powder (EP) is a very common component in the meat, bakery and confectionery food industry due to its excellent foaming, gelling and emulsifying functions compared to other similar ingredients. Although, the presence of egg yolk material in EP gives it the emulsifying function, however, for health reasons consumers often avoid yolk containing products due to higher risk of coronary disease attributed to cumulative effect of cholesterol deposit in the blood vessel lining. Because of high cholesterol content of yolk, application of high heat during spray drying its presence in EP can also predispose the product to oxidative changes leading to production of oxysterol-a highly toxic compound as well as off odor development in the product during storage. Thus, egg white powder or it derivatives without yolk materials would be a better alternative where emulsifying function is not required. Consequently, starch-albumen powder (SAP) was conceived partly as a preserved and more stable form of liquid poultry egg and partly as healthier ingredient to replace whole egg powder due to absence of cholesterol containing yolk (Shittu and Ikpasa, 2006).

Reports have shown that pan-dried albumen (egg white) powders have better quality than spray dried alternatives (Bergquist 1986) due to little or no alteration of functionality in the latter than the former. However, pan drying of albumen may be too slow, high energy consuming and throughput is not commercially feasible. Pre-concentration of albumen prior to drying could be used to decrease the energy demand and improve the capacity of such a dryer (Mohr *et al.* 1987). We have previously reported that addition of dried starch to reduce the initial moisture content of egg albumen resulted to about 21% lesser drying to produce a new food ingredient that could find several applications in food processing (Shittu et al., 2010).

This paper therefore reports our findings on the effect of two independent drying variables (drying temperature and starch content) on the functional properties of the starch-albumen powder (SAP) using a convective tray dryer. The appropriate combination of the drying variables to give optimal quality of coated fried yam chips was also determined.

MATERIAL AND METHODS

Materials

Fresh eggs used in this research were purchased from a poultry farm near University of Agriculture, Abeokuta, Ogun State, Nigeria. Native cassava starch used in this research was procured from Lafenwa Market in Abeokuta, Ogun State, Nigeria.

Experimental design

The influence of drying temperature and level of starch inclusion at five levels and constant air velocity was studied using two-factor central composite rotatable experimental design. Since denaturation of protein and starch gelatinization can occur rapidly at temperatures above 60°C, the drying temperature of 40 to 60°C were used. The actual values of the coded variables and the various combinations of the process variables were shown in Table 1.

Table 1: Coded and actual values of the drying variables

Independent variables	**Standardized levels**[*]				
	-1.414	**-1**	**0**	**+1**	**+1.414**
Drying temperature (°C)	35.86	40.00	50.00	60.00	64.14
Starch content (%)	5.86	10.00	20.00	30.00	34.14

* α = 1.414 (the coded axial distance from the center point).

Starch-albumen powder production

The eggs were washed, broken manually and the egg white (albumen) was carefully separated from the yolk with minimum yolk contamination. The egg albumen was then mixed gently without foaming with native cassava starch for about 60 sec in a Kenwood laboratory size blender, poured on a flat tray and dried in a locally fabricated convective dryer preset at different temperature and constant air velocity of 4.5 m/s (Figure 1). The dried flakes obtained were then milled into powder.

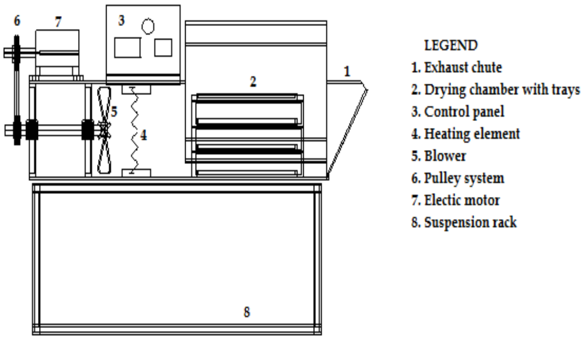


Figure 1: Schematics of the prototype convective dryer used for producing starch-albumen flakes

Moisture content

The moisture content of the samples was determined according to AOAC (2000). Five grams of the samples (SAP and fried yam chips) were weighed using sensitive balance (METTLER PM 400, Metler-Toledo, Switzerland) into petri dishes of known weight, dried at 105°C for 5 h, cooled in glass desiccators and weighed again. Moisture contents were calculated as percent of weight loss after drying on dry basis.

Fat absorption capacity of SAP

This was determined using the method described by Beuchat (1977) with little modification as reported by Shittu *et al.* (2006). One gram of SAP sample was mixed with 10ml of vegetable oil in a weighed centrifuge tube. The slurry was then agitated in a vortex mixer for 2min, allowed to stand at 28°C for 30 min and then centrifuge at 5000 rpm for 20 min. The clear supernatant was thereafter decanted and discarded while the adhering drops of oil were removed. The tube was then weighed and the weight of oil absorbed by 1g of the SAP sample was calculated and expressed as the fat absorption capacity.

Water absorption capacity of SAP

This was determined using the method described by Beuchat (1977) with some modification as reported by Shittu *et al.* (2006). One gram of SAP sample was mixed with 10 ml distilled water in a weighed centrifuge tube. The slurry was then agitated in a vortex mixer for 2 min, allowed to stand at 28°C for 30 min and then centrifuge at 5000 rpm for 20 min. The clear supernatant was thereafter decanted and discarded while the adhering drops of water were also removed. The tube was then weighed and the weight of water absorbed by 1 g of the SAP sample was calculated and expressed as the water absorption capacity.

Coating pickup

The coating pickup was measured after coating but before frying. This was determined using the method published by Hsia *et al.* (1992) as reported by Maskat *et al.* (2005). The weight of the yam slice before (Y) and after coating (C) were recorded. The percentage coating pickup was thereafter calculated as:

$$\%\,\text{Coating Pickup} = \frac{100 \times (C - Y)}{Y} \qquad (1)$$

Oil uptake in coated fried yam chips

The fat content was determined using the method described by AOAC (2000) with slight modification. The dried samples were weighed and pre-soaked in petroleum ether for 48 h before extraction in Soxhlet apparatus for 4 h. After extraction, the solvent was evaporated by drying in an oven, cooled in desiccators and weighed. The oil content was then calculated as follows:

$$\%\ \text{Oil content} = \frac{100 \times (X - Y)}{X} \qquad (2)$$

Where X is initial weight of sample before extraction and Y is the final weight of sample after extraction.

Color of the coated fried yam chips

The samples were snapped using Sony digital camera 13.6 Mega pixels (model No DSC-W300) under daylight conditions. Color of each side of four snapped fried chips were cropped making a total of eight and the color parameters (L*, a* and b*) were determined using CorelDraw Graphics Suite X5 software. The browning index (BI) was thereafter calculated using the formula below:

$$\text{BI} = \frac{100 \times (X - 0.31)}{0.17} \qquad (3)$$

$$\text{X} = \frac{(a^*) + 1.75(L^*)}{5.645(L^*) + (a^*) - 3.012(b^*)} \qquad (4)$$

Where L* is lightness color parameter; a* is redness color parameter; and b* is yellowness color parameter

Sensory acceptability

Samples of the coated fried yam slices and an uncoated fried yam slices were presented randomly to 50-member panelist for the overall acceptability evaluation of the samples using a 9 – point hedonic scale with 1 for "dislike extremely" and 9 for "like extremely" for each of the attributes.

Data analyses

All the experimental trials were carried out in triplicates. The experimental data were fitted to a second order regression model of the form:

$$y = \beta_o + \sum_{j=1}^{k} \beta_j X_j + \sum_{j=1}^{k} \beta_{jj} X_j^{\,2} + \sum_{i=1}^{k} \sum_{j=1}^{k} \beta_{ij} X_i X_j + \varepsilon \qquad (5)$$

β_0, β_i, β_j, and β_{ij} are the regression coefficients for intercept, linear, quadratic, and interaction coefficients, respectively and are coded independent variable, ε is the error term. The parameters of response surface regression equations were determined using Design Expert 7 (Stat-Ease Inc., USA). Correlations between the independent variables and the dependent variables were also studied using SPSS 15.0 Package (SPSS Inc., USA).

RESULTS AND DISCUSSION

Functional properties of SAP

Coatings materials are applied on food surface in powder form (breading) or may be reconstituted (batter) prior to use. The primary functions of coating food prior to frying is to reducing oil uptake as well as contributing to sensory (appearance and textural) appeal of the product. Therefore, it is important the material's functional properties be appropriate for the intended use. Since coating powder is used on wet surface, the water absorption characteristics may be important to maximize coating pick-up. Similarly, reduced oil absorption capacity may also be important to reduce oil uptake during frying. Similarly, for storage stability of the powder's moisture content should be minimal.

The moisture content (MC) of the SAP powder which ranged between 4.46 and 8.10 (%, db), were significantly different ($p<0.05$). These values are within the range needed for shelf stability of powdered products. The water (WAC) and oil absorption (OAC) capacities also ranged from 1.04 to 1.33 and 0.86 to 1.18 g/g, respectively. Only the OAC of SAP was affected by the main effect of drying temperature (Table 2) but the squared effect of temperature affected all the three properties. The starch content of the starch-albumen slurry only affected the coating pick-up (CPU). The observed increase in OAC with drying temperature (DT) above 50^{o}C (Figure 2) might be attributed to the increased denaturation and dissociation of the protein constituents that may occur on heating which unmasks the non-polar residues from the interior of the protein molecule. This also implies that drying of starch-albumen slurry should be dried below

Fried chips' properties

The L-values measured on a scale of 0 (dark) to 120 (light) for fried chips ranged between 90 and 102. Also, the BI values which is an indicator of degree of color purity as well as measure of browning of the chips, ranged between 12 and 97. These values differ significantly ($p<0.05$) among the chips samples. Significant effect of starch content (SC) and its

Table 2: Response surface regression parameters of SAP and coated fried chips properties

Term	MC	WAC	OAC	CPU	L	BI	OU	MCC	Acceptability
Constant	50.46	-1.120	2.750	27.60	113.1	-16.55	116.9	-67.88	4.922
Temperature (T)	-1.56	9.2E-02	-7.7E-02*	-0.42	-1.10E-02	4.11	-2.53*	2.47*	1.6E-02
Starch (S)	-0.58	1.2E-02	-7.0E-02	-0.98*	1.43*	-4.37	-3.31**	3.89**	0.21
T×T	1.5E-02**	-9.7E-04**	8.2E-04*	2.2E-02	1.4E-02*	-4.7E-02	1.9E-02	-1.6E-02	1.9E-04
S×S	1.3E-02**	-4.9E-04	1.7E-04	8.7E-02	-3.6E-02	2.0E-02	2.0E-02*	-4.8E-02**	-3.0E-02
T×S	9.8E-04	2.2E-04	6.1E-06	1.2E-02	-2.6E-02*	4.3E-02	4.4E-02**	-3.4E-02*	-1.9E-03
Goodness of fit parameters									
Sig. P	0.002	0.042	0.160	0.656	0.003	0.147	0.020	0.002	0.744
R^2 (%)	89.63	74.40	61.63	32.50	88.63	62.72	80.46	90.03	27.72
PRESS	21.23	0.197	0.315	12.29	249.8	54.15	249.8	250.1	8878
Critical values of independent variables									
Drying Temperature (Min)	51.3	64.1	46.7	ND	64.1	35.9	35.9	35.9	ND
Starch Content (Min)	20.4	5.9	20.4	ND	34.1	34.1	34.1	5.8	ND
Drying Temperature (Max)	ND	50.0	64.1	64.1	35.9	46.1	ND	ND	35.8
Starch Content (Max)	ND	23.3	5.9	34.1	34.1	5.9	ND	ND	23.6

ND: Not determined

Table 3: Pearson's correlation of SAP and coated fried chips properties

Parameter	MC	WAC	OAC	CPU	L	BI	OU	MCC	Acc
MC	1.00								
WAC	-0.86**	1.00							
OAC	0.40	-0.63*	1.00						
CPU	0.49	-0.51	0.37	1.00					
L	0.18	-0.18	0.12	-0.57*	1.00				
BI	-0.01	-0.15	-0.03	0.31	-0.18	1.00			
OU	0.38	-0.53	0.52	0.73*	-0.48	0.35	1.00		
MCC	-0.72**	0.55	-0.01	0.66**	0.16	-0.29	-0.59*	1.00	
Acc	-0.10	-0.19	0.31	-0.17	0.16	0.02	0.05	0.20	1.00

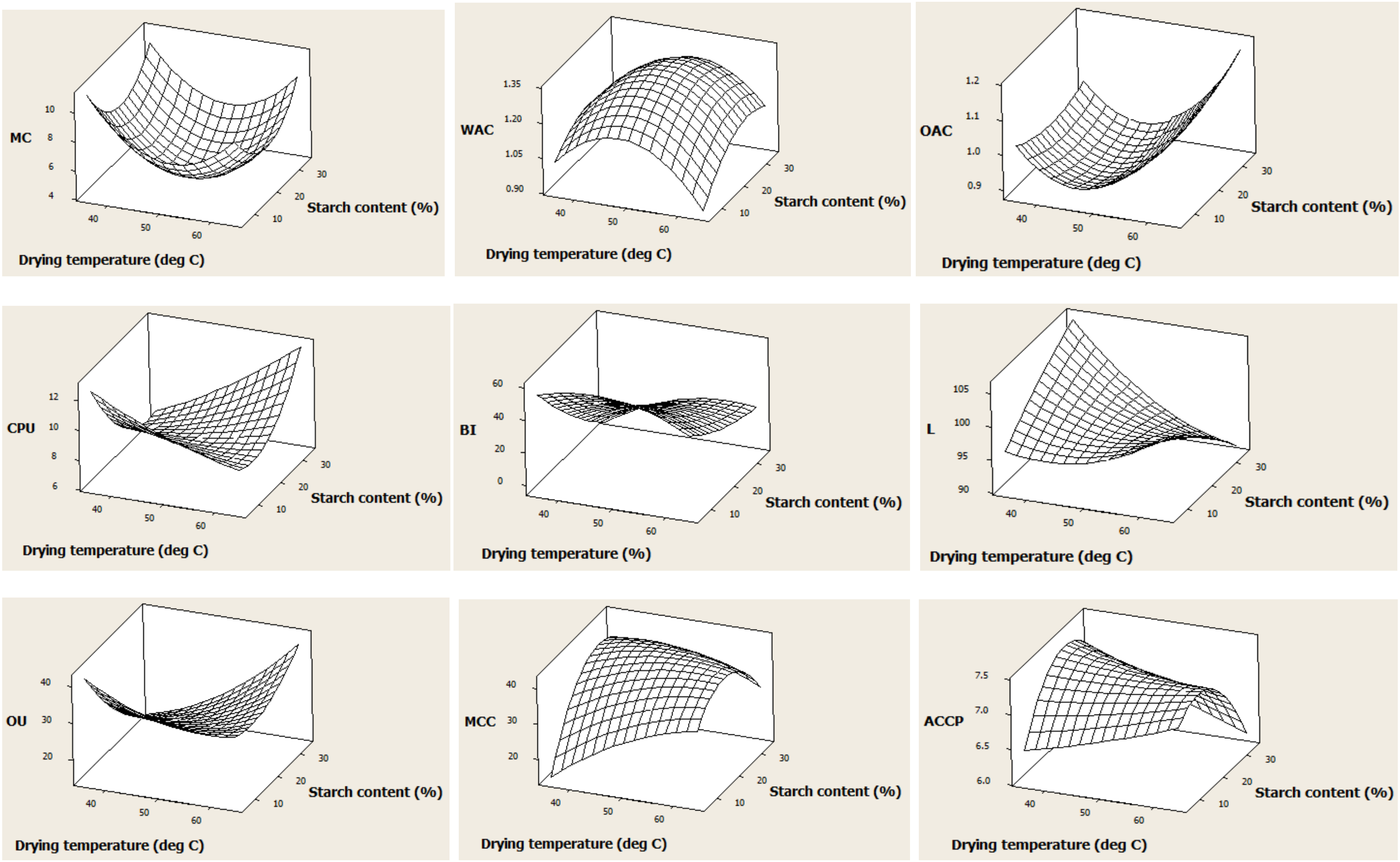


Figure 2: Response surface curves of the SAP and fried chips properties

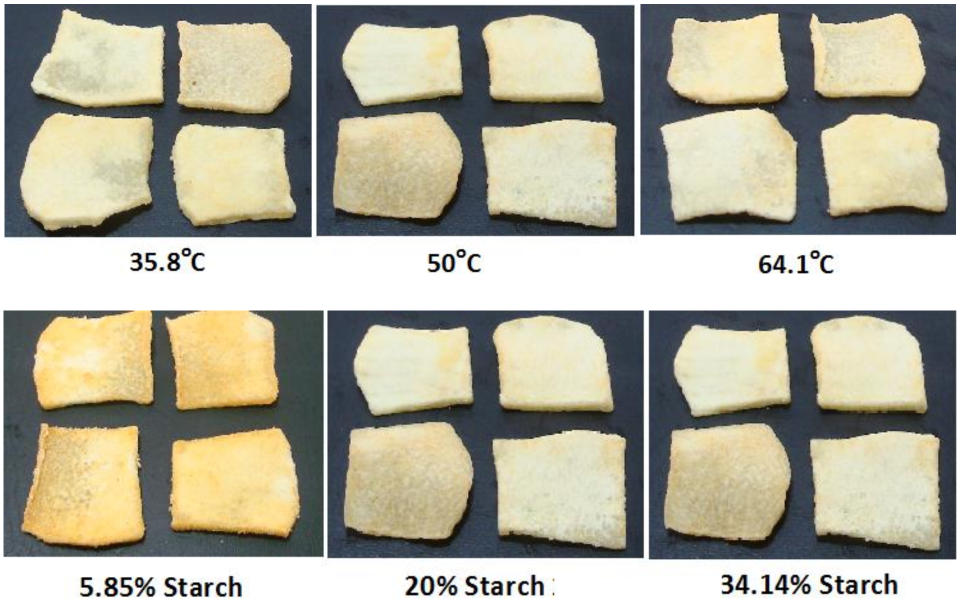
interaction with the drying temperature (DT) was observed on L-value (Table 3).Increased starch content gave lighter chips (Figure 3). BI was neither influenced by drying temperature nor starch content. This might be due to the fact that BI value is also dependent on other color parameters a^* and b as shown in equations 3 and 4. Based on the values of a^* (-3 to 3) and b^* (11-40), the chips are more yellowish than reddish which underscore why the BI values were generally low. Moreover, browning (or Maillard) reaction that causes browning takes place only in the presence of amino acid and reducing sugar at high temperature. Starches contain no reducing sugar in the native form as used in this study. The little browning that was observed may be due to the sugar in the liquid albumen; this may be responsible for the observed reduction of BI value with SC (Figure 3)

As shown in Table 3, MC of SAP had significant negative correlation with water absorption capacity (WAC). This means that greater level of drying of SAP could lead to higher moisture absorption during use. This could explain why higher MC of SAP is also associated with reduced moisture content of fried chip. This result has implications for fried food’s textural and taste properties. For example,

Both the SAP and the yam tissue used contain negligible fat. Therefore, the oil uptake (OU) was predominantly due to diffusion of frying oil into chips. The OU value ranged between19 and 34%. OU was significantly affected by the DT and SC. Increased DT caused reduced oil uptake whereas it was increased with SC (Figure 2). Increased drying temperature gave higher moisture content in fried chips (MCC) but the increment is starch content dependent. This is evident with the saddled response shown by OU to starch and drying temperature in Figure 2. Drying the starch-albumen mash at lower temperature favored lower OU probably due to lower starch damage which could have reduced the oil absorption into the starch granule. Drying at higher temperature caused increased OU with higher starch content. It is also noteworthy that CPU correlated positively with OU ($r=0.73$, $p<0.05$)), implying that higher CPU is associated with higher OU. This might be due to the presence of protein in coating material.

Response surface regression of SAP and fried yam chips properties against the drying variables

Table 3 shows the parameters of the response surface regression models derived for the measured properties of the SAP and fried yam chips. Significant regression models were only obtained for predicting two properties of dried SAP (C, and WAC) and three properties of coated fried chip (L, OU and MCC) with coefficient of determination ranging between 74 and 90%.



35.8°C 50°C 64.1°C

5.85% Starch 20% Starch 34.14% Starch

Figure 2: Effect of drying temperature and starch content on the appearance of SAP coated fried chips

Optimization of drying variables

The critical values of the variables to minimize or maximize the SAP and fried chips properties are presented in Table 4. Since product requirement may be different, these results are important for subsequent production of SAP as a functional food ingredient in various applications. It is obvious that the DT and SC required for minimizing and maximizing different SAP properties are different. However, to produce SAP for use as coating in fried yam chips presented in this work, the global objective of maximizing acceptability (7.0) and minimizing chips oil uptake (19.41%), and chips moisture (28.23%), the predicted drying temperature and starch content are 40°C and 11.3%, respectively.

CONCLUSIONS

This study has shown that drying temperature and starch content had significant influence on the functional properties of starch-albumen powder. The optimal drying temperature and starch content. Optimal performance of SAP as coating material in fried yam chips production can be achieved by using drying temperature and starch content of 40°C and 11.3%, respectively. Our finding also shows that the two drying variables could be manipulated to achieve SAP with functional properties useful for many food applications.

NOMENCLATURE

MC	Moisture content of SAP	%, db
WAC	Water absorption capacity of SAP	g/g solid
OAC	Oil absorption capacity of SAP	g/g solid
CPU	Coating pick up of un-fried chip	%, w/w
L	Lightness of fried chip	
BI	Brownness index of fried chip	
OU	Oil uptake of fried chip	%, w/w
MCC	Moisture content of fried chip	%, w/w

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