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Effect of some hydrocolloids as adjuncts on the quality of whole egg or egg white coated fried yam chips

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Abstract

Effect of different hydrocolloids (xanthan gum (XG), carboxymethyl cellulose (CMC) and gum tragacanth (GT)) and their concentrations (0.05-0.15 g/kg) on quality of whole egg (WE) and egg white (EW) coated fried yam chips were investigated. Parameters studied include coating pick-up (CPU) prior to frying, and moisture content (MC), moisture retention due to hydrocolloid (MR), fat content, oil uptake due to hydrocolloid (OU), instrumental colour and textural properties of coated fried yam chips. CPU was significantly ($p<0.05$) influenced by the type and concentration of hydrocolloid, egg form. Using EW in coatings recorded significantly ($p<0.05$) higher CPU compared with WE. MC and fat content increased with increased hydrocolloid concentration. Significant linear models for predicting the effect of CPU on fat content ($0.905<r^2<0.988$) and exponential model for predicting the effect of MC on peak force ($r^2 = 0.842$) were generated. Use of EW in coatings resulted in lower MC and fat content. Chips' lightness increased while browning index (BI) and peak force (or fracturability) decreased with increased hydrocolloid concentration.

Key words: Hydrocolloids, frying, egg white, whole egg, yam chips, quality, moisture retention, oil uptake, browning, texture.

Introduction

Frying, one of the oldest cooking methods widely used to prepare tasty and crispy foods, is defined as the immersion of a food product in edible oil or fat heated above the boiling point of water [1]. These conditions lead to high-heat transfer rates largely responsible for the modification of the physical, chemical and sensory properties of fried products and may be considered a dehydration process [2].

Modification of appearance and flavour in fried foods generally affect the overall quality of the products [3]. Generally, fried chips quality is assessed by attributes such as colour, moisture content, degree of oil uptake and crispiness [4] and these are influenced by factors such as quality of raw materials (foods, frying oil), frying temperature, frying duration, processing method, food geometry, fryer and food pretreatments such as coating.

Coating the surfaces of products before deep-fat frying has been shown to have effects on quality of fried products such as control of moisture loss and oil uptake during frying, as well as provision of nutrient, a crisp texture and the development of desired colour [5].

Different studies have been carried out to determine the effect of coating on quality of fried products. Baker and Scott-Kline [6] reported that broiler drumstick coated with batters containing egg white had higher coating pick up and was preferred to those without egg white. Similarly, coatings led to significant reduction in oil absorption [5, 7] and improved the crispness of the final fried product [8, 9]. Despite the obvious advantages of coatings on fried products, coating of product prior to frying has some technological challenges. Among them is the loss of coating material during frying, also known as the "blow-off" phenomenon which is caused by the rapid evaporation and migration of moisture from the product being fried [10, 11]. Loss of coating invariably leads to loss of product material and hastens the degradation of the frying medium as a result of overcooking of the blown off coating particles [12]. However, application of hydrocolloids as an adjunct in the coating has been reported to reduce coating loss during frying [13]. Other functions of hydrocolloid reported by several authors for different food systems includes moisture control and firming in bread [14], stabilization by viscosity increase in beverages [15] and improvement of rheological properties of texture in dairy products [16]. Specifically, hydrocolloids in fried foods are known to cause reduced oil uptake, their presence in coating materials also assists in enhancing batter viscosity, improving coating adhesion and pick-up properties, better mechanical resistance of the outer crust and freeze-thaw stability [7, 17].

Fried yam chip, a popular street vended delicacy in sub-Saharan Africa is a typical yam food that meets the time saving requirement of the fast food industry. A variant of fried yam chips popularly consumed in Nigeria is that coated with whipped whole egg. However, some health conscious consumers may prefer egg-white as coating due to absence of yolk that contains significant amount of cholesterol. Despite the acceptance of fried yam chips as a convenient, ready to eat snack, published information on the quality of fried yam chips containing egg-based coatings is scarce.

The objective of this work was to investigate the effects of xanthan gum (XG), carboxymethyl cellulose (CMC) and gum tragacanth (GT) as a coating adjunct on the quality of whole egg and egg white coated fried yam chips.

Materials and Methods

White yam (*Dioscorea rotundata*) procured from local market in Ibadan and fresh poultry eggs obtained from a poultry farm were used for the research. Refined, bleached and deodorized palm olein oil (Gino Oil, Malaysia) was obtained from a food market in Ibadan. Xanthan gum (XG) (Quest International, Brazil), carboxymethyl cellulose (CMC) (Walocel CRT 30.000 PA, Dow Wolf Cellulosic GMBH) and gum tragacanth (GT) (Fufeng Group, China) were supplied by Mekang Resources and Allied Distribution Limited Lagos.

Preparation of coating formulation: Fresh poultry eggs were washed with distilled water to remove extraneous materials. Egg white was obtained by careful separation from egg yolk [4]. The different coating systems were formulated by mechanically mixing the hydrocolloids (XG, CMC or GT) with whole egg or egg white using commercial blender (HR2001, Philips, China) at a proportion of 0.05 to 0.150 g of hydrocolloid/kg of coating formulation. Mixing was continued until the mixture was uniform and free of lumps.

Yam chips preparation: White yam tubers were peeled using a stainless steel knife and cut into pieces of 30 mm by 45 mm dimension. The pieces were chipped using vegetable multi-slicer (SF 923-1, CEE Square Ltd., Houston, Texas, USA) into 2.5 mm thickness and washed using distilled water to remove surface starch. Yam slices were then blanched in hot water in a water bath (NE 122/15136, Clifton, England) at 75°C for 5 min [18] and allowed to drain. Blanched slices were blotted using paper towel to remove loose materials adhering to the surface and excess water prior coating [2].

Coating and frying operations: Yam chips were weighed into 50 g batches and dipped piece by piece into coating formulations. They were allowed to drain for 30 s to remove excess coating material. The slices were reweighed after coating. The chips were deep fried in 2 l of hot oil contained in an electric fryer (S-516, Saisho, Hong Kong, China) equipped with a 2 kW electric heater and temperature control of ±1°C. Slices were fried at 180°C for 5 min [4] for each set of treatment and controls. Excessive oil was allowed to drain off from the chips for about 50 s [19] after removal from the fryer. The chips were allowed to cool to room temperature before reweighing. The frying experiments were carried out in triplicates.

Coating pick-up: Amount of coating adhering to the substrate was considered as coating pick-up (CPU) and calculated as

$$CPU(\%) = \frac{C - Y}{Y} * 100 \tag{1}$$

where Y is the weight of yam chips and C is the weight of yam chips after coating.

Analyses of fried samples: Moisture of the samples was determined by weight loss after drying 5 g samples in a forced air oven at 105°C for 24 h [20].

Increase in moisture, that is, moisture retention due to hydrocolloid (*MR*) was calculated:

$$MR\ (\%) = \frac{(MC_h - MC_{wh}) * 100}{MC_{wh}} \tag{2}$$

where MC_h, MC_{wh} are moisture content of fried coated chips with and without hydrocolloid, respectively.

The fat content of the samples was determined by *n*-hexane extraction of the sample using Soxhlet apparatus for 6 h [21]. Oil uptake due to hydrocolloid (OU) was calculated as follows:

$$OU(\%) = \frac{(FC_h - FC_{wh}) * 100}{FC_{wh}} \tag{3}$$

FC_h and FC_{wh} are the fat contents of fried coated chips with and without hydrocolloid, respectively.

Colour parameters of hydrocolloid-egg based coated fried yam chips were studied using the method described by Shittu *et al.* [14]. Digital images of the samples were acquired under two fluorescent lamps of 60 cm (Philips, TLD series 90, 18 W/965), with a color temperature of 6500°C (D65, daylight) with a digital camera (DSC-W300, Sony Corporation, Japan) positioned vertically at equal distance above the food sample and with no flash. The maximum resolution of the camera was 13.2 Megapixel. The angle between the axis of the camera lens and the lightning source axis was maintained at 45° to capture the diffuse reflection responsible for the color. The chips images were cropped, processed and analyzed using Corel PHOTO-PAINT 12 software (Corel Corporation, USA). The histogram of lightness/darkness (L), greenness/redness (a) and blueness/yellowness (b) color channels according to this software ranges from -127 to +128 (i.e. L value for Black = 0 to -127 and White = 0 to +127; b value for green = 0 to -127 and red = 0 to +128; b value for blue = 0 to -127 and yellow = 0 to +128). The following equations were used to convert these values to the usual 0 to 100 scale for L* and -100 to +100 scale for a* and b* channels:

$$L = 100 * \bar{L} / 128 \text{ since } \bar{L} \text{ is} > 0 \text{ (lightness)} \tag{4}$$

$$a = 100 * \bar{A} / 128 \text{ since } \bar{A} \text{ is} > 0 \text{ (redness)} \tag{5}$$

$$b = 100 * \bar{B} / 128 \text{ since } \bar{B} \text{ is} > 0 \text{ (yellowness)} \tag{6}$$

$\bar{L}$, $\bar{A}$, and $\bar{B}$ are the mean values of lightness (L), redness (a) and yellowness (b) colour channels (respectively) generated from corel PHOTO-PAINT 12 environment [14].

The *hue* (H) and browning index (BI) were calculated as follows:

$$H = \tan\text{-}1\ b/a \tag{7}$$

$$BI = (100(x - 0.31)) / 0.172 \tag{8}$$

where

$$x = (a + 1.75L) / (5.645L + a - 3.012b) \tag{9}$$

Texture of the fried chips samples was evaluated using a universal testing machine (M500-25kN, Testometric AX, Rochdale, England). Coated fried yam chips of uniform size were selected. The plunger attached to the upper jaw of the machine was a cylinder with a flat end of 6 mm diameter base. The samples were placed on a platform of 10 mm diameter hole. The cylindrical plunger moving with a speed of 30 mm/min over the distance of 150 mm was used to press the samples in the middle. The scheme of deformation, i.e. force of deformation (F) against distance curve, was generated and displayed on the monitor connected to the equipment.

Statistical analysis: All analyses were done in triplicate. Data were analysed using SPSS version 15.0 software and charts generated using Microsoft Office Excel 2007. One-way analysis of variance (ANOVA) was used to study the difference between means and where differences existed ($p < 0.05$); Duncan's Multiple Range Test was used to separate the means. Multivariate analysis of variance (MANOVA) using general linear model (GLM) was employed to study the effect of independent variables on the quality of the chips.

Results and Discussion

Effect of hydrocolloids on coating pick-up prior to frying: Effect of independent variables, hydrocolloid type, hydrocolloid concentration and egg form on some quality attributes of coated fried yam chips is presented in Table 1. The values of coating pick-up ranged from 20.29 to 55.5%. Hydrocolloid type, hydrocolloid concentration and egg form had significant ($p<0.05$) influence on coating pick-up (Table 2). Xanthan gum conferred the highest coating pick-up probably due to greater stability offered by the structural properties of XG. The xanthan gum molecule contains side chains that bind its helical structure thus making the molecule a stiff rod with extra ordinary stability [22]. It has also been reported to be completely soluble in both hot and cold water and imparts high solution viscosity at low concentration [23]. The observed increase in CPU with increased hydrocolloid concentration (Table 1) is similar to the observation of Hsia *et al.* [24] on chicken nuggets and could be due to increase in viscosity. Egg white coated chips had higher CPU compared to whole egg coated chips. Two reasons could be adduced for this; higher moisture content in egg white could have resulted in more hydrogen bonding and thus increasing the viscosity of the mixture or interference of the lipids in the yolk of whole egg which could have limited the water absorption of hydrocolloids. Since CPU is related to cooked yield of the fried product [17] it is expected that higher CPU observed for XG and egg white combination will give high cooked yield.

Effect of hydrocolloids on moisture content: After frying, moisture content and moisture retention due to hydrocolloid ranged between 3.99 to 29.04% and 164.73 to 638.31%, respectively (Table 1). The hydrocolloid type, and concentration as well as form of egg used had significant effect ($p<0.05$) on moisture content and moisture retention while the interaction of HT and HC significantly affected ($p<0.05$) moisture retention (Table 2). Generally, the hydrocolloids enhanced moisture retention in coated fried yam chips due to their hydrophilic nature. Xanthan gum and CMC conferred the highest and the least moisture retention, respectively. The observed variation may be due to difference in water binding capacity of gums [7]. Alloncle and Doublier [25] reported that XG in solution has higher water binding capacity than CMC because XG in its chemical structure has higher number of free carboxyl groups [26]. This causes it to have more sites for hydrogen bonding and hence greater water retention. The increase in moisture content with increased hydrocolloid concentration could be due to increase in CPU which presented an increased protective layer that prevented moisture migration from the product being fried. This is similar to the observation of Akdeniz *et al.* [7] who studied the effect of batters containing gum on fried carrot slices.

The higher MC in fried yam chips coated with whole egg plus hydrocolloid when compared to that of egg white could be explained from two perspectives; higher interaction between whole egg and hydrocolloids which enabled efficient and effective coverage of the product in controlling moisture loss and the ability of lechitin in egg yolk to hold water because of its emulsifying ability as reported by Mohamed *et al.* [8].

Table 1. Effect of independent variables on some quality attributes of coated fried yam chips.

EF	HT	HC (g/Kg)	CPU (%)	MC (%)	Fat (%)	MR (%)	OU (%)
Egg white	XG	0.05	36.68±3.94^{ef}	14.37±0.72^{ef}	25.02±0.14^{b}	247.18±17.45^{c}	-14.08±0.48^{c}
		0.10	45.46±3.20^{ghi}	19.24±0.54^{gh}	35.43±0.73^{g}	364.73±12.97^{ef}	21.65±2.50^{g}
		0.15	55.50±2.05^{k}	28.74±0.51^{jk}	41.33±0.26^{j}	594.20±12.32^{i}	41.94±0.89^{k}
	CMC	0.05	26.65±4.49^{c}	10.96±0.91^{c}	22.30±0.13^{a}	164.73±21.98^{a}	-23.4±0.45^{c}
		0.10	34.91±3.92^{def}	13.16±0.14^{d}	30.51±0.52^{d}	217.87±3.38^{b}	4.77±1.80^{e}
		0.15	44.30±1.15^{gh}	20.14±0.72^{h}	39.33±0.39^{i}	386.47±17.39^{fg}	35.06±1.33^{hi}
	GT	0.05	32.66±3.19^{cde}	14.27±0.75^{ef}	23.95±1.15^{b}	244.61±18.12^{c}	-17.77±3.94^{ab}
		0.10	40.51±5.79^{fg}	18.95±0.34^{g}	33.25±0.71^{f}	357.81±8.22^{e}	14.17±2.44^{f}
		0.15	52.24±3.30^{jk}	28.01±0.66^{j}	38.25±1.81^{hi}	576.49±15.98^{i}	31.34±6.21^{h}
Control I	-	-	16.64±2.48^{ab}	4.14±0.12^{b}	29.12±0.39^{c}	-	-
Whole egg	XG	0.05	31.63±1.49^{cde}	15.15±0.53^{f}	30.28±0.40^{cd}	285.09±13.47^{d}	-0.57±1.32^{d}
		0.10	41.25±8.45^{fg}	20.01±0.40^{h}	37.53±0.47^{h}	408.81±10.23^{g}	23.23±1.55^{g}
		0.15	51.24±4.05^{ijk}	29.04±0.45^{k}	42.60±0.64^{j}	638.31±11.49^{j}	39.88±2.10^{jk}
	CMC	0.05	20.29±4.75^{b}	11.13±0.60^{c}	24.35±0.03^{b}	183.05±15.26^{a}	-20.04±0.10^{ab}
		0.10	28.72±2.31^{cd}	13.86±0.50^{e}	31.94±0.09^{e}	252.37±12.65^{c}	4.88±0.30^{c}
		0.15	41.20±5.98^{fg}	21.59±0.45^{i}	37.44±0.39^{h}	448.81±11.46^{h}	22.94±1.28^{g}
	GT	0.05	29.11±2.23^{cd}	14.99±0.53^{f}	30.12±0.76^{cd}	281.19±13.57^{d}	-1.09±2.50^{d}
		0.10	35.62±5.25^{ef}	19.83±0.50^{gh}	35.48±0.99^{g}	404.07±12.71^{h}	16.51±3.25^{f}
		0.15	48.85±2.38^{hij}	28.96±0.42^{k}	41.68±1.50^{j}	636.27±10.65^{j}	36.87±4.91^{ij}
Control II	-	-	12.69±1.07^{a}	3.99±0.23^{b}	30.45±0.19^{d}	-	-

EF: egg form (type); HT: hydrocolloid type; HC: hydrocolloid concentration; CPU: coating pick-up; MC: moisture content; MR: moisture retention; OU: oil uptake. Means with same letter in column are not significantly different ($p < 0.05$).

Table 2. P-values of the main and interactive effects of independent variables on quality parameters of coated fried yam chips.

Processing variables	CPU	MC	MR	Fat	OU	Lightness	Hue	BI	PF
HT	***	***	***	***	***	0.252	0.283	0.367	0.179
HC	***	***	***	***	***	***	*	***	**
EC	***	***	***	***	***	*	***	***	0.148
HT*HC	0.963	***	***	**	**	0.902	0.884	0.301	0.665
HT*EC	0.869	0.816	0.614	***	***	0.990	0.475	0.872	0.970
HC*EC	0.784	0.655	*	***	***	0.882	0.198	0.644	0.777
HT*HC*EC	0.974	0.442	0.565	*	*	0.844	0.888	0.964	0.901

HT: hydrocolloid type; HC: hydrocolloid concentration; EC: egg form; MC: moisture content; MR: moisture retention; OU: oil uptake; BI: browning index; PF: peak force; *: p≤0.05; **: p≤0.01; ***: p≤0.001.

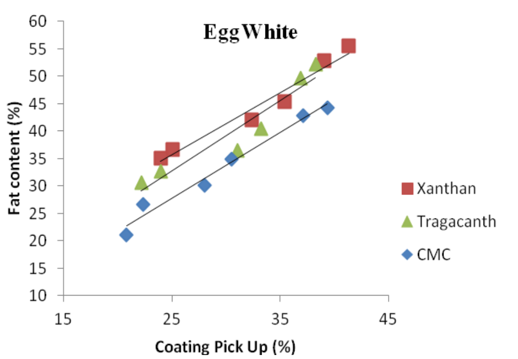
Table 3. Linear regression equation for predicting the effect of CPU on fat content.

	Equation	R^2
Egg white		
XG	Y= 1.138x + 7.197	0.963
CMC	Y= 1.197x + 2.174	0.977
GT	Y= 1.279x + 0.807	0.905
Whole egg		
XG	Y= 1.535x – 14.62	0.988
CMC	Y= 1.627x – 20.41	0.957
GT	Y= 1.692x – 22.50	0.971

CPU: coating pick up; XG: xanthan gum; CMC: carboxymethyl cellulose; GT: gum tragacanth; x: CPU; Y: fat content; R^2: coefficient of determination.

Effect of hydrocolloid on fat content and fat uptake: It is expected that the use of hydrocolloids in frying will lead to reduction of fat uptake in fried products [27]. This reduction was only observed when 0.05 g of hydrocolloid was added per kg of coating. For all the hydrocolloids, concentrations higher than 0.05 g/kg in the coating formulation led to an increase in fat uptake. This could be as a result of increased coating pick-up and by extension increased protein content which could have led to higher swelling of coatings during frying. The protein might have created a lipophilic surface which caused entrapment of oil in the product [28]. As the protein is swelling, capillaries are created. The longer the depth of capillaries, the higher the oil uptake [28].

Significant linear correlation was observed between coating pick up and fat content ($r = 0.853$, $p < 0.01$) when data from all the treatments were pooled. Generally, fat content varied linearly with CPU (Fig. 1). The respective linear regression models for predicting fat content from CPU are presented in Table 3. From the linear regression parameters, increased CPU was found to lead to higher fat content with the use of gum tragacanth than the other two hydrocolloids.



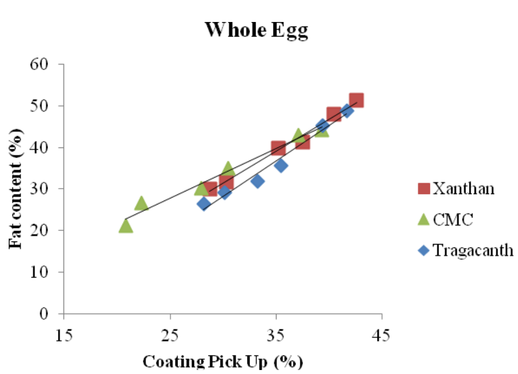


Figure 1. Linear relationships between coating pick up and fat content.
CMC: carboxymethyl cellulose.

Chips with CMC in coating had the least fat content while that of XG had highest. Egg white plus hydrocolloid coated chips had reduced oil uptake compared with that of whole egg despite higher CPU. This could probably be because of lipophobic nature of egg white [8]. Higher oil content for whole egg coated chips might be due to the presence of certain proteins of egg yolk (lipoproteins and phosphoproteins) which could have reduced the surface tension between oil and water and resulting in greater oil absorption [8].

Effect of hydrocolloids on colour parameters of coated fried yam chips: The effects of hydrocolloids on colour parameters of coated fried yam chips are presented in Table 4. It could be noted that lightness, *L**, values increased with increased hydrocolloid concentration. A major factor that determines color changes in fried food is browning reaction which is often affected by temperature, composition, water activity and so on. The increased *L** value could be due to increase in moisture content (or water activity) of the coating with increased hydrocolloid concentration. Akdeniz *et al.* [7] had earlier observed that the ability of gums to bind moisture prevents dehydration and inhibits Maillard browning reaction. This could also explain the observed higher *L** values for whole egg coated chips.

Hue angle (*h*) values, of all the chips were above 70°, showing a very clear transition from red to yellow. This indicates the

Table 4. Effect of hydrocolloids on colour parameters of coated fried yam chips.

EC	HT	HC (g/Kg)	Lightness (L^*)	Hue angle (h)	Browning index (BI)
Egg white	XG	0.05	$63.30 \pm 2.14^{a-d}$	$75.33 \pm 2.01^{a-e}$	94.91 ± 5.50^{gh}
		0.10	$66.30 \pm 2.28^{a-e}$	74.43 ± 0.65^{abc}	$84.97 \pm 4.07^{d-h}$
		0.15	71.47 ± 3.79^{de}	73.62 ± 1.58^{ab}	72.43 ± 4.85^{cde}
	CMC	0.05	61.67 ± 9.19^{ab}	$75.50 \pm 2.02^{a-e}$	97.26 ± 23.83^{h}
		0.10	$66.70 \pm 2.39^{a-e}$	73.84 ± 1.54^{ab}	78.06 ± 6.06^{cde}
		0.15	$69.20 \pm 5.66^{b-e}$	72.95 ± 2.31^{a}	70.51 ± 5.77^{cd}
	GT	0.05	62.30 ± 1.54^{abc}	$75.60 \pm 0.98^{a-e}$	$93.58 \pm 1.45^{f-h}$
		0.10	$65.63 \pm 10.39^{a-e}$	$74.85 \pm 1.83^{a-d}$	$85.21 \pm 14.51^{d-h}$
		0.15	$67.08 \pm 5.28^{a-e}$	73.20 ± 2.20^{a}	$79.92 \pm 10.98^{d-g}$
Control I	-	-	$65.78 \pm 6.90^{a-e}$	81.73 ± 1.50^{g}	51.03 ± 13.80^{b}
Whole egg	XG	0.05	$67.00 \pm 1.14^{a-e}$	78.86 ± 1.49^{f}	$83.60 \pm 3.68^{d-h}$
		0.10	$69.99 \pm 4.77^{b-e}$	77.94 ± 2.07^{ef}	76.59 ± 6.80^{cde}
		0.15	70.63 ± 0.88^{cde}	77.41 ± 1.13^{def}	70.04 ± 0.84^{cd}
	CMC	0.05	$64.18 \pm 1.79^{a-e}$	77.38 ± 0.63^{def}	$86.79 \pm 2.51^{e-h}$
		0.10	$68.08 \pm 0.66^{a-e}$	$76.29 \pm 0.76^{b-f}$	71.18 ± 2.92^{cde}
		0.15	72.35 ± 1.81^{e}	77.27 ± 2.05^{def}	64.00 ± 1.31^{bc}
	GT	0.05	$64.41 \pm 2.39^{a-e}$	$77.12 \pm 1.53^{c-f}$	$82.93 \pm 2.05^{d-h}$
		0.10	$67.27 \pm 2.72^{a-e}$	$77.17 \pm 1.61^{c-f}$	76.30 ± 11.71^{cde}
		0.15	$69.33 \pm 3.51^{b-e}$	$76.87 \pm 0.24^{c-f}$	70.07 ± 4.74^{cd}
Control II	-	-	60.65 ± 4.80^{a}	84.27 ± 3.03^{h}	$78.43 \pm 17.62^{c-f}$

Means with same letter in column are not significantly different ($p < 0.05$).

development of golden brown colour [29] which is highly preferred by fried chips consumers. The higher *h* values observed for whole egg coated chips could be due to carotenoid content of egg yolk component of whole egg.

Browning index, BI, represents the purity of brown colour and is reported as an important parameter in processes where enzymatic and non-enzymatic browning takes place [29]. In the present study, BI ranged from 51.03 to 97.26. The decrease of BI with increased hydrocolloid concentration could be due to increase in moisture and oil in the samples which impaired Maillard reaction [7].

Effects of hydrocolloids on fracturability of coated fried yam chips: Texture attributes are among the factors that influence sensory liking of fried products such as chips. Peak force (PF) is the force at the site of pronounced change in curvature. It is also called fracturability and is one of the parameters that is being used in the objective measurement of texture. The highest PF value observed for CMC in coating formulation as shown in Fig. 2 could be due to its low water absorption capacity and hence low moisture retention. Lower PF observed for whole egg coated fried yam chips when compared with egg white coated samples could be related to higher moisture retention ability of whole egg because of the emulsifying effect of its egg-yolk component. General decrease in PF (fracturability) of the chips with increased hydrocolloid concentration (Fig. 3) could be due to the increase in moisture retention and attendant mealy texture of the chips.

Data on PF of all the fried yam chips samples with different MC was fitted to three regression models namely, linear, quadratic and exponential (Fig. 4). All the three gave good fit to the data.

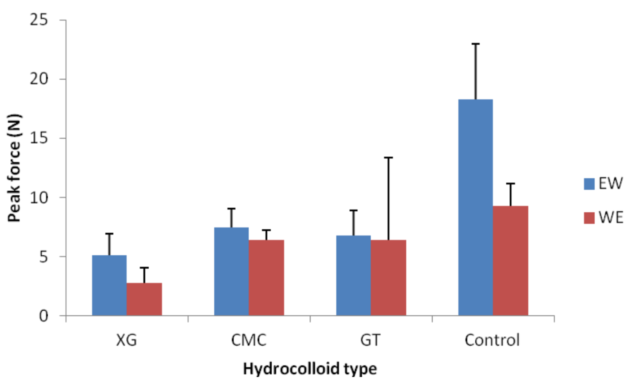


Figure 2. Effect of hydrocolloids and egg type on fracturability of coated fried yam chips.
EW: egg white; WE: whole egg; XG: xanthan gum; CMC: carboxymethyl cellulose; GT: gum tragacanth.

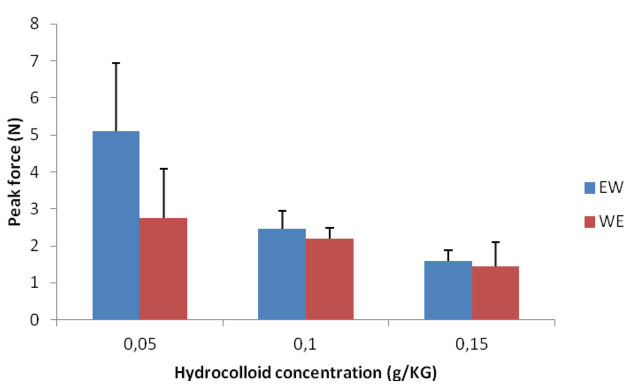


Figure 3. Effect of hydrocolloid (XG) concentration and egg form on peak force of coated fried yam chips.

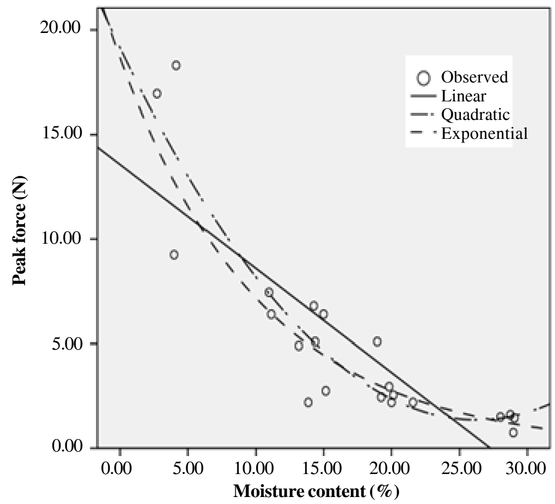


Figure 4. Curve fit of the effect of MC on PF hydrocolloid-egg base coated fried yam chips.

However, the exponential form of the model gave the best fit (R^2 = 0.842, p<0.01). The final form of the equation is:

$$PF = 18.665e^{-0.096MC} \qquad (10)$$

Brittle behaviour, a measure of crispness, of coated fried yam chips was lost as moisture content increased. This was detected as a change in the pattern and in the value of parameters derived from the force-deformation curves. As moisture content increased with increase in hydrocolloid concentration, a shift from brittle fracture to plastic flow was observed (Fig. 5a-c). This increase in MC led to tenderness of the chips and the resultant effect according to Miranda and Aguilera [32] is a drop in the modulus of the chips due to increased mobility of macromolecules (Table 4).

Conclusions

Generally, the use of hydrocolloids improve coating pick up (CPU), which was higher with egg white than with whole egg. Addition of XG gave higher CPU compared to other hydrocolloids. However, inclusion of hydrocolloids in coating formulation generally led to higher moisture and fat contents of fried yam chips. It is noteworthy that the use of CMC in coating formulation gave the least oil uptake, and enhanced crispiness of coated fried yam chips. This study further shows that to reduce oil uptake, not more than 0.05 g hydrocolloid per kg coating should be used.

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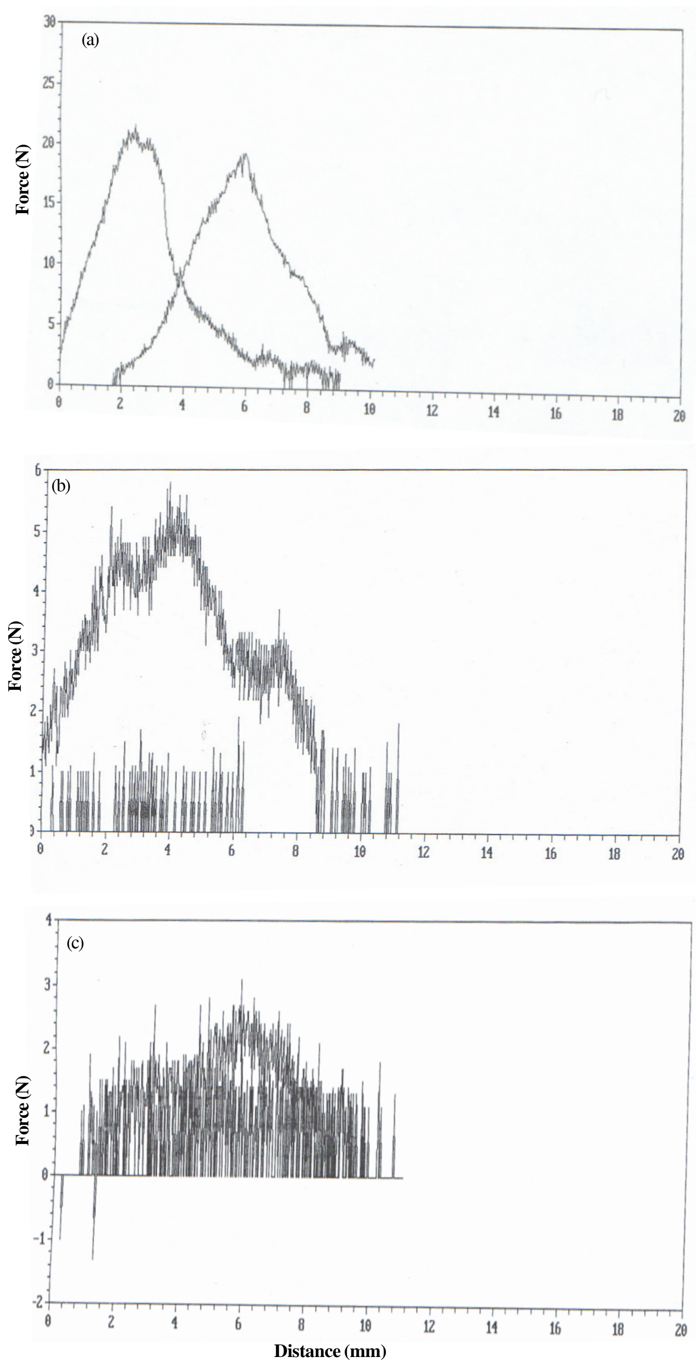

Figure 5. Effect of hydrocolloid concentration on brittle behaviour of coated fried yam chips; (a) 0.5, (b) 1.0 and (c) 1.5%.