

The effect of extrusion variables on the Colour of *Dakuwa* extrudates produced from blends of Sorghum (*Sorghum bicolour L*) Groundnut (*Arachis hypogea L*) and Tigernut (*Cyperus esculentus*)

ABSTRACT

*A three factor three level full factorial experimental design was used to determine the effect of extrusion variables on the colour of the extrudate with (90, 100 and 110°C) barrel temperature (50:20:30, 20:25:25 and 50:30:20) feed composition for ratios of sorghum groundnut and tiger nut respectively at 150rpm screw speed and 3mm die diameter using a twin screw food extrusion cooker (SLG-65-III Model China). Version 16 of Genstat was used in analysing the result. The result reveal that extrusion significantly ($p<0.05$) affect the colour of the extrudate. The total colour differences between the extruded samples (ΔE) were determined. The average ΔE values ranged from 7.13 to 38.82. Statistical analysis showed that the barrel temperature feed composition and feed moisture content had an effect on the total colour differences ($P<0.05$) of *Dakuwa* extrudates. The highest ΔE was found at 90oC barrel temperature, 50:25:25 feed composition and 22% feed moisture content.*

Keywords: colour, extrusion, dakuwa extrudates

1.0 INTRODUCTION

1.1 Extrusion

Extrusion is one of the food engineering processes that involve a combination of transport processes, including flow of materials within the system, thermal energy transfer to and within the material, and mass transfer to and within the material during extrusion. The flow of materials within the channels of the system occurs in all types of extrusion. Food ingredients of various types may be processed by extrusion and are referred to as *extrudates*. All ingredients involved in the extrusion process flow through a channel with a defined geometry.

Extrusion technology, well-known in the plastics industry, has now become a widely used technology in the agro-food processing industry, where it is referred to as extrusion-cooking. It has been employed for the production of so-called engineered food and special feed. Extrusion cooking is a thermodynamically efficient industrial method of cooking and drying a wide range of foods based on cereals or vegetable proteins or mixtures of both Carl *et al.*[1].

Extrusion cooking process has become a highly trendy process in the cereal, snack, and pet food industries that use starch and protein as raw materials to produce highly valuable food product Lin *et al.*[2]. Generally speaking, extrusion-cooking of vegetable raw materials deals with extrusion of ground material at baro-thermal conditions. With the help of shear energy, exerted by the rotating screw, and additional heating of the barrel, the food material is heated to its melting point or plasticating point. Food extruders (extrusion-cookers) belong to the family of HTST (high temperature short time)-equipment, capable of performing cooking tasks under high pressure. This is advantageous for vulnerable food and feed as exposure to high temperatures for only a short time will restrict unwanted denaturation effects on, for example, proteins, amino acids, vitamins, starches and enzymes. Physical technological aspects like heat transfer, mass transfer, momentum transfer, residence time and residence time distribution have a strong impact on the food and feed properties during extrusion-cooking and can drastically influence the final product quality Leszek, [3]. Extrusion cooking

is used worldwide for the production of expanded snack foods, starch modified ready-to-eat cereals, baby foods, pasta and pet foods Malleshi, [4]; Deshpande *et al.*[5]. This technology has many distinct advantages including versatility, low cost, better product quality, and no process effluents Abbott [6]; Camire *et al.*[7].

Sorghum (*Sorghum bicolor*) (L.) Moench) is a critically important food crop in Sub-Saharan Africa on account of its drought tolerance. The increased use of sorghum as food in this region could alleviate the problem of chronic under nourishment, as sorghum is much better suited to cultivation in the semi-arid tropics than non indigenous cereals such as wheat or maize. According to Ryden *et al.* [8], grain sorghum is cultivated by farmers on subsistence level in the semi-arid tropics worldwide and consumed as staple food by humans. The continent of Africa is one of the largest producers of sorghum and produces approximately 18.5 million metric tons of sorghum annually.

Groundnut has contributed immensely to the development of the Nigerian economy. From 1956 to 1967, groundnut products including cake and oil accounted for about 70% of total Nigeria export earnings, making it the country's most valuable single export crop ahead of other cash crops like cotton, oil palm, cocoa and rubber Harkness *et al.*[9]. Presently, it provides significant sources of cash through the sales of seeds, cakes, oil and haulms Olorunju *et al.*[10]. Groundnut plays an important role in the diets of rural populations, particularly children, because of its high contents of protein and carbohydrate. It is also rich in calcium, potassium, phosphorus, magnesium and vitamin E.

Tiger nut tubers belong to the food stuffs having a high nutritional potential but which remain under-exploited Ukwuru *et al.*[11] and Bamishaiye *et al.* [12]. This nutritional value of the tubers is appreciable and it varies from an area to another. In Egypt, it is widely eaten as soaked tubers and is used, like in China, as a liver tonic, to heal stomach pain, mouth and gum ulcers, promote normal menstruation, enhance production of breast milk in nursing mothers and in folk medicine it used as a colon evacuator and cleaner. These numerous nutritional advantages, health benefits and therapeutic advantages associated with tiger- nut makes it more attractive for fortification of dakuwa used in manufacture of snacks products.

Dakuwa is a cereal and legume based snack item prominent throughout northern Nigeria. It consists basically of roasted tiger nut and roasted groundnut paste, while roasted sorghum flour is optional depending on cultural provision Bagirei [13]. Colour is an important quality factor directly related to the acceptability of food products, and is an important physical property to report for extrudate products. Color changes can give information about the extent of browning reactions such as caramelization, maillard reaction, degree of cooking and pigment degradation during the extrusion process Ilo and Berghofer, [14]. Colour change occurring during the extrusion process is as a result of non-enzymic browning, colour degradation and improvement in nutrient density of the extrudates. This observed effect correspond to the literature reported by Yusuf *et al.* [15] that extrusion increased the water absorption index, water solubility index, water hydration capacity and a decrease in viscosity of the extrudates. Another finding by Yusuf *et al.* [16] reveals that extrusion improves the amino acid profile of dakuwa extruded. Also it was found that the protein of dakuwa extrudate were improved as a result of extrusion Yusuf *et al.*[17]. The increase in nutrient density is characterize by colour change occurring during the extrusion process.

Colour is an important component of the visual appearance of foods. It may also be related to the wholesomeness of foods. Along with flavour and texture, colour is often perceived as a valuable quality factor in the acceptability and marketability of food products. Colour is perceived three dimensionally, based on responses of three different receptors (red, green and blue) in the human eye [18], yet all three dimensions may not be of practical importance. The Judd–Hunter L, a, b and CIELAB L*, a*, b* are alternative colour scales

used to measure the degree of lightness (L^*), redness or greenness ($\pm a^*$) and yellowness or blueness ($\pm b^*$), with the CIELAB scale being most commonly used for the evaluation of colour in foods [19]. Conversion of a^* and b^* readings to hue and chroma values gives results more closely associated with human perception [20].

The objective of this study was to evaluate the effect of extrusion variables on the colour characteristics of *Dakuwa* extrudates.

2.0 MATERIALS AND METHODS

2.1 Sources of raw material

The raw materials used includes Sorghum (*Sorghum bicolor* L) red variety, groundnut (*Arachis hypogea* L) red skin and tiger nut (*Cyperus esculentus* L) brown variety all were procured in Jimeta modern market, Yola north local government area of Adamawa State. The granulated red pepper (*Capsicum annum*) was also obtained in the same market.

2.2 Preparation of raw materials

Sorghum, groundnut and tiger nut were sorted manually, cleaned and washed with clean water and allowed to dry in conventional oven at 50°C for 1hour, the sorghum groundnut and tiger nut were roasted at 150 °C for 30 minutes in baking oven. The sorghum groundnut and tiger nut was size reduced to flour and sieved to obtained the particle size of 0.05mm, while the groundnut was grinded to paste using grinding machine (7 hp India). The sorghum, groundnut and tiger nut grits was mix together in a ratio of 50:20:30 50:25:25 50:30:20 respectively using Horbart mixer (model number A 200) for 10 minutes. To 1.5 kg of this mixture 2.5 % of granulated red pepper (*Capsicum annum*) was added and mixed together. The mixture was then packaged and ready for extrusion.

2.3. Full factorial design

To construct an approximation model that can capture interactions between N design variables, a full factorial approach may be necessary to investigate all possible combinations Montgomery,[21]. A *factorial* experiment is an experimental strategy in which design variables are varied together, instead of one at a time. The lower and upper bounds of each of N design variables in the optimization problem needs to be defined. The allowable range is then discretized at different levels. If each of the variables is defined at only the lower and upper bounds (two levels), the experimental design is called 2^N full factorial. Similarly, if the midpoints are included, the design is called 3^N full factorial. Factorial designs can be used for fitting second-order models. A second-order model can significantly improve the optimization process when a first-order model suffers lack of fit due to interaction between variables and surface curvature. A general second-order model is defined as

$$y = a_0 + \sum_{i=1}^n a_i x_i + \sum_{i=1}^n a_{ii} x_i^2 + \sum_{i=1}^n \sum_{j=1, j \neq i}^n a_{ij} x_i x_j \quad \text{Eq. (1)}$$

Where x_i and x_j are the design variables and a are the tuning parameters. The construction of a quadratic response surface model in N variables requires the study at three levels so that the tuning parameters can be estimated. Therefore, at least $(N+1)(N+2)/2$ function evaluations are necessary. Generally, for a large number of variables, the number of experiments grows exponentially (3^N for a full factorial) and becomes impractical. A full factorial design typically is used for five or fewer variables. However in this experiment three factor three levels full factorial design were used for the design as shown in table 1 and 2 Yusuf *et al.*[21].

2.4 Experimental Design

A Three factor Three level Experimental Design (3x3x3) was use to determine the effect of extrusion on the colour of Nigerian indigenous cereals and legume based snack product (*Dakuwa*).The extrusion variables that were considered includes: Feed moisture

content (Fm), Barrel temperature (Bt) and Feed composition (Fc), each were varied at 3, 3 and 3 levels respectively as shown in Figure 2, Table 1 and 2. Thus, this is a 3 (feed moisture) x 3 (barrel temperature) x 3 (feed composition) full factorial design treatment for a mixture of flour. The analysis of variance was carried out to investigate the effect of operating conditions on the final extruded product quality using version 16 of Gen stat software Genstat, [22]. 3D histogram was used to predict the influence of independent extrusion variables on the colour parameters of the extruded. All the graphical presentations were carried out using Microsoft of excel

2.5 Extrusion processing

The extrusion cooking process was performed using a pilot scale co-rotating twin screw food extrusion cooker (SLG65-III Model China) the extruder has a feeder at the top with constant feed rate, it also has a control panel board where the barrel temperature was set. The machine has constant screw speed of 150 rpm and a die diameter of 3mm. The twin screws within the barrel are surrounded with heaters controlled at the control panel board. The grits was alternatively feed in to the extruder inlet by volumetric feeder at a feed rate of 0.04kg/s. The temperature of the three zones of the extruder was controlled by Eurotherm controller and was read on separate control panel board. Extruded samples were collected when the extrusion process parameters reach steady states. Steady state was reached when there was no visible drift in torque and die pressure.

Necessary calibration and adjustment of the barrel temperature of the extruder was performed prior to the main extrusion cooking process. Feed rate and screw speed were constant. The feed composition was varied at 50:20:30, 50:25:25 and 50:30:20 ratios of sorghum, groundnut and tiger nut respectively. The barrel temperature of zone three, which was located just before the die was allowed to operate at different temperatures ranging from 90 °C to 110 °C. By looking at the characteristic of the products from the extrusion, the barrel temperature was selected for the experiment. The moisture content of the material was adjusted to give moisture contents of 18 %, 22 % and 26 % by using hydration equation (2).

$$W_a = S_w \times \left(\frac{M - M_o}{100 - M} \right) \quad \text{Eq. (2)}$$

Where:

W_a = Weight of water added (g)

S_w = Sample flour weight (g)

M_o =Original flour moisture content (% weight base)

M = Required dough moisture level (% weight base).

The extrusion experiment was conducted using 3 factor 3 level experiment design (3^3), with 1 factor representing extruder barrel temperature, with levels (90 °C 100 °C 110 °C). 2nd Factor representing feed composition with levels (50:20:30, 50:25:25, 50:30:20) for sorghum groundnut and tigernut respectively, the 3rd factor representing feed moisture, with levels 18 % 22 % 26 % as shown in Table 1 and 2. The extruder barrel temperature was set at 90 °C and 9 samples were run, and at 100 °C another 9 samples were run. Finally at 110 °C the remaining 9 samples were then run. As shown in Table 1 and 2 for experimental design in coded and natural forms. At each case the screw speed remains constant at 150 rpm and the die diameter remain 3 mm. The extruded were cooled dried and stored in a polythene bag for further analysis.

Table 1: - Factors and levels of the 3x3x3 full factorial experimental design

	Symbol	Factor Levels		
Factors	X	1	2	3
Blends ratio				

197	(Sorghum, groundnut, tiger nut)	X ₁	50:20:30	50:25:25	50:30:20
198	Barrel temperature (°C)	X ₂	90	100	110
199	Feed moisture (%)	X ₃	18	22	26

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201 Table 2. Experimental Design of Extrusion Experiment in their Coded Form

Independent variables in coded form				
Runs	Bt (X ₁) Levels	Fc (X ₂) Levels		
	1 2 3	1 2 3	1 2 3	Fm (X ₃) Levels
1	1	3	2	
2	1	3	1	
3	1	3	3	
4	1	2	2	
5	1	2	1	
6	1	2	3	
7	1	1	2	
8	1	1	1	
9	1	1	3	
10	2	2	3	
11	2	2	2	
12	2	2	1	
13	2	3	1	
14	2	3	2	
15	2	3	3	
16	2	1	1	
17	2	1	3	
18	2	1	2	
19	3	2	3	
20	3	2	3	
21	3	2	1	
22	3	1	1	
23	3	1	3	
24	3	1	2	
25	3	3	3	
26	3	3	2	
27	3	3	1	

202 The experiment was carried out in randomized order. (Bt) = Barrel temperature with levels 1 2 and 3 represents
 203 90 100 & 110 °C, (Fc) = Feed composition with levels 1, 2 and 3 representing 50:20:30, 50:25:25 and 50:30:20
 204 for ratios of sorghum groundnut and tiger nut respectively. (Fm) = Feed moisture with levels 1, 2 and 3 which
 205 represent 18 %, 22 % and 26 % respectively.

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207 *Total colour difference (ΔE)*

208 The extrudates were finely ground using a hammer mill in the laboratory. The colour
 209 parameters determined for the raw blends (non-extruded) and extruded samples included L^* ,
 210 a^* and b^* values (CIE Lab system) using a Colour capture and Identifier developed by JQR

APPS Latest version of 2.2.8. Total colour difference (ΔE) was calculated applying the equation 3

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad \text{Eq (3)}$$

Where L , a , and b are the values for the extruded Samples; L_0 , a_0 , and b_0 are the values for the raw mixture. The colour parameters are the mean values of ten observations.

3.0 CHAPTER THREE

3.1 RESULTS AND DISCUSSION

Colour act as one of the triggers for acceptance of snack foods. Digital imaginary in conjunction with adobe Photoshop helps identification of variations in the colour of extruded product. The least L^* (degree of lightness) value of 11.04 were recorded at design point 3 representing 90°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 26% feed composition, however the highest L^* -value of 70.48 was recorded at design point 4 representing 90°C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 22% feed moisture content (Table 3). The least L^* value recorded at design point 3 could be as a result of high groundnut content in the blend that is characterized with high oil content that decreases the lightness of the extruded, on the other hand high L^* value recorded could be as a result of low groundnut content in the blend formulation.

The influence of independent variables reveals that barrel temperature, feed composition and feed moisture content significantly ($p < 0.05$) affect the L^* value of the extruded (Figure 1). As the barrel temperature increased from 90°C to 100°C, the L^* value increased from 35.13 to 41.16 however at 110°C the L^* -value decreased to 37.86. The decrease of L^* -value at high temperature could be as a result of non-enzymic browning reaction which occurs at high temperature. A similar finding has been reported by Leonel *et al.* [23], Bhattacharya *et al.* [24]. Another finding by Hanuman and Savita [25] in the extrusion of honey enriched whole grain cereal flour extrudates reveals that extrusion at lower temperature (100°C) produced extruded with highest L^* -value while extrusion at highest temperature (200°C) resulted in extruded with lowest L^* -value.

Table 3. Combine effect of extrusion variables on Total colour differences of Dakuwa extrudates

Sn	<u>Bt</u> 123	<u>Fc</u> 123	<u>Fm</u> 123	L^*	a^*	b^*	ΔE
1	1	3	2	27.89	18.11	8.99	15.66
2	1	3	1	15.89	8.14	7.10	16.90

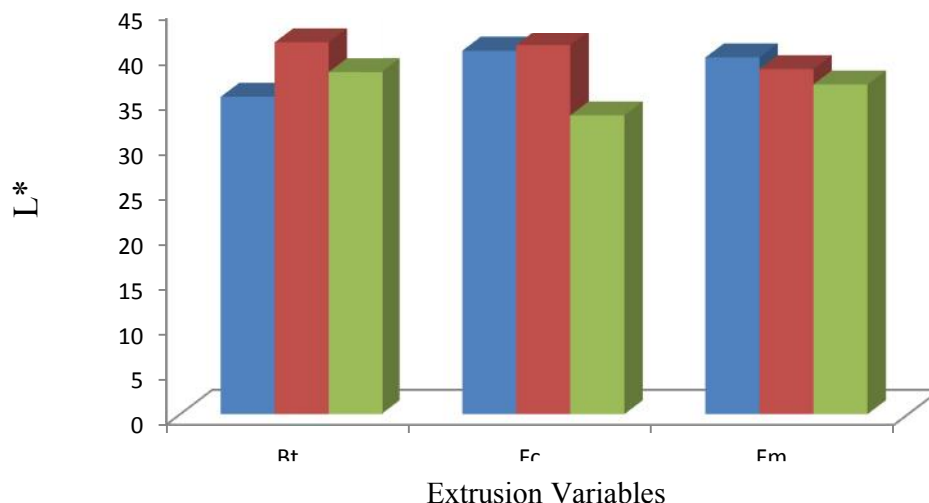
253	3	1	3	3	11.04	11.05	6.38	22.10
254	4	1	2	2	70.48	6.99	2.08	38.82
255	5	1	2	1	34.12	33.55	19.59	15.88
256	6	1	2	3	17.65	10.67	6.23	16.35
257	7	1	1	2	28.79	18.58	10.09	27.76
258	8	1	1	1	58.79	8.19	7.52	34.86
259	9	1	1	3	51.56	26.31	21.11	34.86
260	10	2	2	3	17.65	10.03	5.04	7.13
261	11	2	2	2	50.85	30.22	18.68	35.94
262	12	2	2	1	42.33	19.91	14.10	22.03
263	13	2	3	1	51.86	17.09	24.85	32.54
264	14	2	3	1	23.19	14.03	10.27	15.02
265	15	2	3	3	48.42	25.44	17.03	30.49
266	16	2	1	1	40.02	23.19	20.92	27.52
267	17	2	1	3	47.87	18.54	20.66	28.02
268	18	2	1	2	37.68	11.52	1.99	9.35
269	19	3	2	2	38.84	20.09	2.24	15.90
270	20	3	2	3	48.61	11.14	8.48	19.07
271	21	3	2	1	41.70	18.36	1.65	17.25
272	22	3	1	1	24.95	10.59	6.67	10.09
273	23	3	1	3	47.33	27.03	21.47	33.30
274	24	3	1	2	25.01	20.13	9.87	18.65
275	25	3	3	3	27.67	12.84	12.78	13.84
276	26	3	3	2	46.01	22.42	13.46	28.50
277	27	3	3	1	45.62	16.24	21.08	25.94

The experiment was carried out in randomized order. (Bt) = Barrel temperature with levels 1 2 and 3 represents 90 100 & 110 °C, (Fc) = Feed composition with levels 1, 2 and 3 representing 50:20:30, 50:25:25 and 50:30:20 for ratios of sorghum groundnut and tiger nut respectively. (Fm) = Feed moisture with levels 1, 2 and 3 which represent 18 %, 22 % and 26 % respectively. L* = degree of lightness, a* = measure the degree of redness or greenness, b* = measure the degree of yellowness or blueness, ΔE = means change of colour.

This may be due to the formation of brown pigments through non-enzymatic Maillard reactions between proteins and reducing sugars that occur during the product processing [26], [27]. Feed composition increasing the level of groundnut from 20 to 30% resulted in darker extruded with a reduction in the degree of lightness or L*-value from 40.22 to 33.07. These could be as a result of high oil content in groundnut that resulted in darker extruded.

Feed moisture content significantly ($p < 0.05$) affect L*-value of the extrudate, increasing the feed moisture content from 18 to 26 % resulted in decreasing the L*-value of the extrudate from 39.48 to 36.49% the result obtained agree with the reported literature of Bakalov *et al.* [28] that L*-value decreases from 71.49 to 68.08 with increasing the moisture content from 16 to 28 % during the extrusion of bean-based extrudates. Also Gujka and Khan [29] reveal that increasing the moisture content resulted in decrease of L*-value of navy, pinto and garbanzo beans extrudates.

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Bt: Barrel temperature Fc: Feeds composition Fm: Feeds moisture

90°C
100°C
110°C

50:20:30
50:25:25
50:30:20

18%
22%
26%

Figure 1. Effect of extrusion Independent variables on L value of the extrudate

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The least a^* (degree of redness or greenness) of 6.99 was recorded at design point 4 represent 90 °C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content. The highest a^* -value of 30.22 was observed at design point 11 represent 100°C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content (Table 3).

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Barrel temperature, feed composition and feed composition significantly ($p < 0.05$) affect the a^* -value of the extruded as shown in Figure 2. Increasing barrel temperature from 90 to 110°C resulted in increasing the degree of redness of the extruded or a^* -value from 15.73 to 17.65. On feed composition increasing the level of groundnut from 20 to 30% resulted in decreasing the degree of redness of the extruded from 18.23 to 16.15. and that could be because of high groundnut content that resulted in decreasing the a^* -value of the extruded. On feed moisture content increasing the moisture content from 18 to 26 % resulted in decreasing the a^* -value from 17.25 to 17.01.

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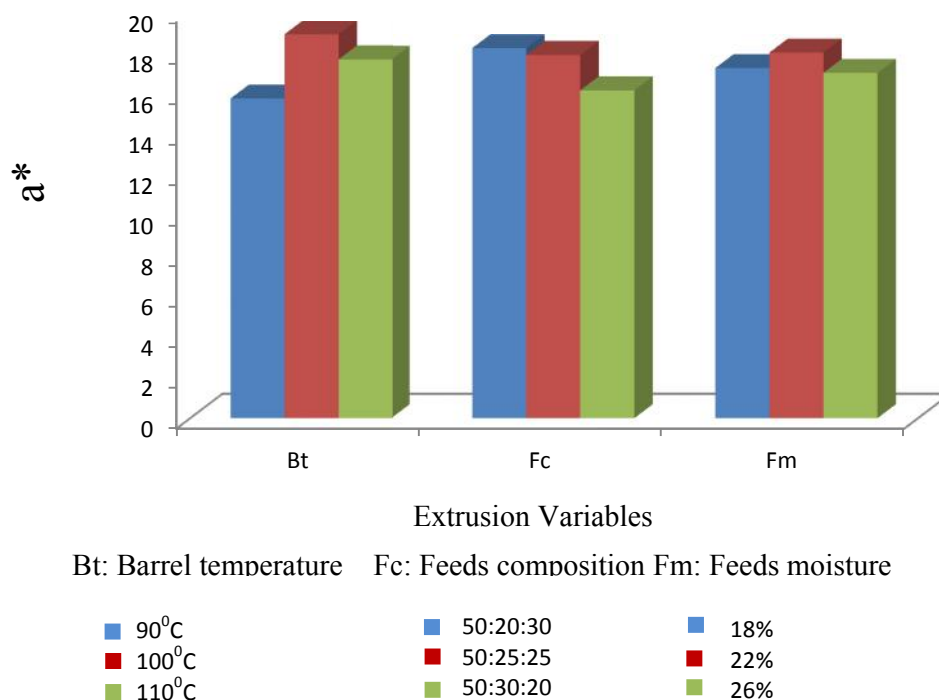
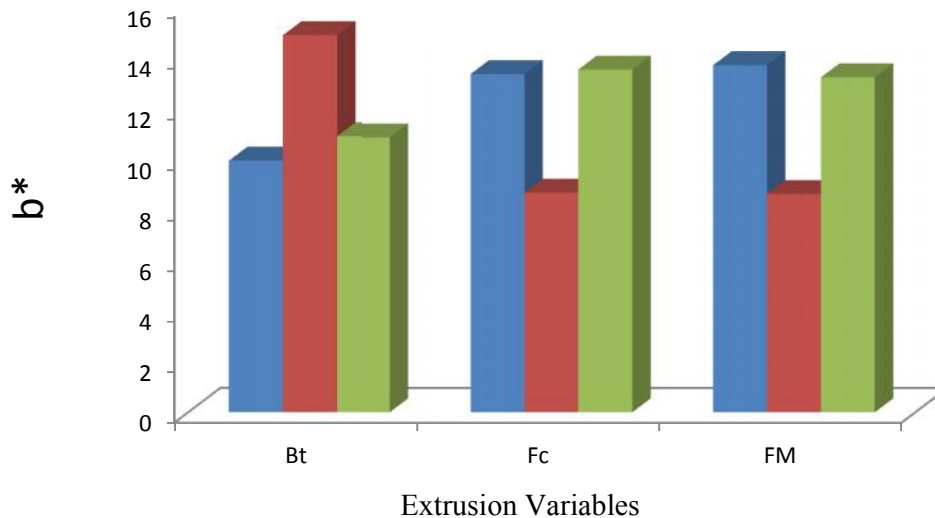


Figure 2. Effect of extrusion Independent variables on the a value of the extrudate

b*-value (measure the degree of yellowness or blueness) ranged from 2.08 at design point 4 representing 90°C barrel temperature 50:25:25 feed composition for sorghum groundnut and tigernut and 22% feed moisture content to 24.85 at design point 13 representing 100°C barrel temperature, 50:30:20 feed composition for ratios of sorghum groundnut and tigernut and 18 % feed moisture content (Table 3). Barrel temperature feed composition and feed moisture significantly ($p < 0.05$) affects the **b***-value of the extruded.

On **b***-value (measure the degree of yellowness or blueness) as shown in Figure 3. Increasing the barrel temperature from 90 to 110°C resulted in increasing the **b***-value of the extruded from 9.90 to 10.86. On feed composition increasing the level of groundnut content from 20 to 30% resulted in increasing the **b***-value from 13.37 to 13.55. The increase could be as a result of yellow nature of groundnut. The increase in the yellowness of the extruded agreed with reported literatures from Leonel *et al.* [30] and Paes and Maga [31]. The change in yellowness during extrusion cooking was most induced by the effects of nonenzymatic browning and pigment destruction reactions. All these differences could have been due to the shear forces generated during extrusion which accelerated the chemical reactions between amino acids and reducing sugars (maillards reaction) that take place during extrusion Guy,[32]. On feed moisture content, increasing the feed moisture from 18 to 26% resulted in decreasing the **b***- value of the extruded from 13.72 to 13.24.

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Bt: Barrel temperature Fc: Feeds composition Fm: Feeds moisture

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353 Figure 3. Effect of extrusion Independent variables on b value of the extrudate

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355 The ΔE (change of colour) value ranged from 7.13 at design point 10 representing
 356 100°C barrel temperature, 50:25:25 for sorghum groundnut and tigernut and 26% feed
 357 moisture content to 38.82 at design point 4 representing 90 °C barrel temperature, 50:25:25
 358 feed composition for sorghum groundnut and tigernut respectively and 22% feed moisture
 359 content (Table 3). Barrel temperature feed composition and feed moisture content
 360 significantly ($p < 0.05$) affect the ΔE value of the extruded (Figure 4). On barrel temperature,
 361 increasing barrel temperature from 90 to 110°C resulted in decreasing the ΔE of the extruded
 362 from 24.69 to 20.28. The decrease of ΔE at high barrel temperature could be as a result of
 363 decline in chemical reactions including non-enzymic browning that resulted in slight change
 364 of colour at maximum temperature.

365 On feed composition, increasing the level of groundnut from 20 to 30% resulted in
 366 decreasing the ΔE value from 22.88 to 22.33. On feed moisture content increasing the feed
 367 moisture content from 18 to 26% resulted in decreasing the ΔE value of the extruded from
 368 22.77 to 22.74. The decrease of ΔE with increase in moisture agreed with report from
 369 Bakalov *et al.* [33].

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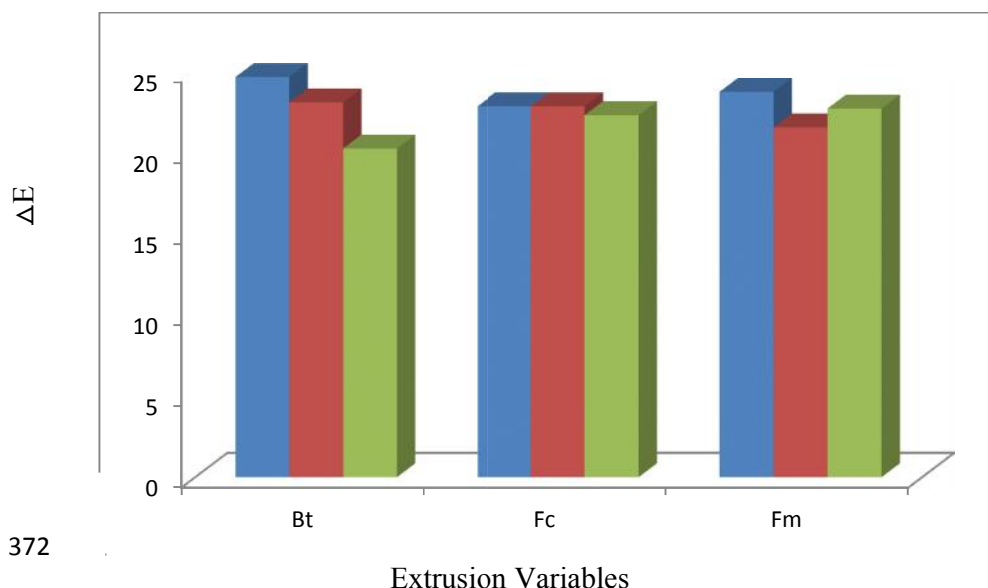


Figure 4. Effect of extrusion Independent variables on ΔE of the extrudate

CONCLUSION

The effect of extrusion variables on the colour of *Dakuwa* extrudates was studied. The average colour differences (ΔE values) between the extruded samples ranged from 7.13 to 38.82. The result further reveal that the highest colour change of the extrudates ΔE was obtained at 90°C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 22% feed moisture content. Statistical analysis showed that the barrel temperature feed composition and the feed moisture content had an effect on the total colour differences ($P < 0.05$) of the extrudates. The result of this research could be used by the processors to select the appropriate colour for their product by varying the processing parameters. Since colour is an important factor due its role in the acceptability and marketability of the product.

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