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EFFECTS OF EXTRUSION COOKING ON PHYSICOCHEMICAL PROPERTIES OF AN EXTRUDED SNACK FROM THE BLEND OF CEREALS AND LEGUMES ENRICHED WITH DATE PALM FLOUR AS POST COVID-19 SNACK FOOD

TA'AWU K.G[1] ., [2]SHUA J. N. AND MAIRO A[1]
[1]Department of Food Science and Technology, Federal Polytechnic Mubi P.M.B 35, Mubi, Adamawa State, Nigeria [2]Department of Animal Health and Production Technology, the Federal Polytechnic, PMB, 35 Mubi, Nigeria

ABSTRACT
The study was conducted to evaluate the effect of extrusion cooking on physicochemical properties of an extruded snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the development of post covid-19 snack food. Various conditions of feed composition (FC), feed moisture content (FMC), and die size (DS) were studied. The results of physiochemical properties of the products showed a relation between bulk density and expansion ratio of extruded materials i.e., the greater the expansion volume, the lower the bulk density. The optimum independent variables conditions were found to be 23.75% FC, 13.43% FMC, 6.0 mm DS with the dispensability 0.50, which produces 0.66 BD, 3.86 WAI, 3.70 WSI, 1.78 ER, and 0.30 OAI. The results also indicated that optimum values can be obtained in the extrusion of snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the development of post covid-19 snack food.

Keywords: *Extrusion, snack, groundnut-cake, optimization, physiochemical, sorghum and date palm*

INTRODUCTION
As expected, a significant change in eating habit is observed with a growing need of convenience foods, different group of people became familiar with

extruded snacks. It is one of the convenience food that can be consumed at any time of the day(Nahemia et al., 2016) . Consumers want snacks, that taste good and smell good, feel good, look good and in addition, nutritionally superior and healthy (Jiangping et al., 2017). In recent years there has been renewed interest in a number of technologies in food processing that brings about changes and impact on the availability and variety of food products. Extrusion cooking is one of the contemporary food processing technologies applied to cereals and legumes that their processing is traditionally time consuming, labour intensive, costly and not efficient. This method is quite not popular in West African countries, especially Nigeria, thus it appears as a natural choice for use and can be applied to mitigate the problems associated with processing of traditional cereal-legumes based foods in terms of improving its functional properties, physical qualities and shelf life which can be used to produce new food products from indigenous raw materials with improved sensory, functional, texture storage ability at low cost (Filli et al., 2012).

However, it has not been applied to sorghum processing and its blends with defatted groundnut cake and date palm which makes it the preferred technology in the study(Yusuf & Filli, 2017). Extrusion cooking used high temperature short time and high shearing force to make a variety of foods such as snacks and which includes mixing, shearing, cooking, plasticizing and forming(Nkama & Filli, 2007). Extrusion technology is becoming more and more popular, with the reduction of cost and time, extrusion has replaced the traditional processing methods in most African countries with Nigeria still lagging behind(Filli et al., 2014). The extrusion cooking gelatinizes the starch component and increase the soluble of dietary fibre content. Moreover, extrusion improves the natural flavour and keeps the natural colour, it also reduces the incidence of lipid oxidation and microbial contamination(Li et al., 2019). Sorghum contains a number of nutrients like carbohydrates, proteins, iron, and calcium; however, sorghum is deficient in lysine and contains some anti-nutritional factors. Date is a delicious fruit with a sweet taste and a fleshy mouth feel. The major component of dates are mainly the sugars; sucrose, glucose, and fructose which may constitute about 70%. The sugars in dates are easily digested and can immediately be moved to the blood after consumption and can quickly be metabolized to release energy for various cell activities (Abiona et al., 2018).

Dates are also good source of fibre, and contain many important vitamins and minerals, including significant amounts of calcium, iron, fluorine, and selenium (Oke et al., 2013). It has a positive impact on health and can prevent the risk of diabetes, hypertension and the increase in bad cholesterol level due to its high nutritional value. Groundnut (Arachis hypogaea) has a high oil and protein contents and also contain higher amounts of methionine and lysine which is deficient in the sorghum(Danbaba et al., 2018). Therefore, Sorghum blend with groundnut cake and date fruit for the production of snack through extrusion will complement each other and facilitate the increase in use of the local crops. The objective of this study was to evaluate the effect of of extrusion cooking on physicochemical properties of an extruded snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the for the development of post covid-19 snack food.

MATERIALS AND METHODS

Study area

The study was conducted at the Livestock Teaching and Research Farm of Federal Polytechnic Mubi, Adamawa State, Nigeria. Mubi lies on latitude 10^0 16′ 8″ N of the equator and longitude 13^0 16′ 14 ″ E of Green-wich Meridian (Anonymous, 2015).Mubi is the second largest to Yola, the state capital. Mubi LGA is located at the northern part of old Sardauna Province which now forms Adamawa north senatorial district as defined by INEC ,2006 (Ajawara, 2006). Mubi region is bounded to the north by Borno state, to the west by Hong and Song LGA and to the south and east by the Republic of Cameroon. It has a land area of about 4,728,77 km^2 and human population of about 151,000 going by 2006 census projected figure (Ajawara, 2006).

Raw Materials Preparation

Sorghum, groundnut cake and date palm were obtained from Hong market in Hong Local Government Area of Adamawa State, Nigeria. High density polyethylene for packaging the products was purchased from poly products Ltd Ilupeju, Lagos. The experiment was carried out in laboratories of Food Science and Technology departments of Micheal Okpara University of Agriculture Umudike, Federal Polytechnic Mubi and Modibbo Adama University of Technology, Yola, Nigeria.

All raw materials were manually sorted to remove all contaminants and impurities. Sorghum grains were washed in portable water and drained through a local perforated basket. The drained sorghum was dried under the sun for three days (72hrs). Fresh date palm fruits were de-pitted, cut into small pieces and dried under the sun for three days, and later milled in a grinder (M-20, KA-werke, GMBH and CO.KG, Staufen Germany) for 2mins.The powder obtained was shifted in a steel-mesh sifter (0.85mm aperture) to obtain fine flour particles. The powder was sealed and stored in a polyethylene bag for further use. Defatted groundnut cake was milled using hammer mill (Iika labortec Hnik, Staufen, Germany) and sieved using 0.85mm sieve and then dried in hot air oven at 60^{0}C for 5hr, allowed to cool and later stored in a polyethylene bag for further use.

Pre-extrusion treatment

The major pre-extrusion treatment to the raw blends was the addition of water to meet the desired feed moisture level (FMC). The initial blend moisture content was determined for each feed composition (FC) in an oven (precision, USA) according to AOAC (2005) in order to determine the amount of water required to bring each raw flour blend moisture to the desired feed moisture (FMC) level based on the experimental design. Twenty (20) different blends of sorghum groundnut cake (GC) and date flour (DF) were formulated to contain 20% DF across all the formulations and different levels of GC ranging between 10-30% with an adjusted FMC between 12 and 18% (w/w) by spraying with a calculated amount of water (Eqn. 1) (Gui & Ryu, 2014). Feed materials were conditioned for 3h to equilibrate at room temperature prior to the extrusion process. The extrusion was performed in a twin-screw extruder (SGL 65) at 140rpm available at the Department of Food Science and Technology, Federal Polytechnic Mubi Adamawa State, Nigeria. The temperature was set at 110^{o}C for the entire sample.

$$\text{Amount of water to be added (g)} = \frac{(M_f - M_i) \text{ x } S_w}{100 - M_f} \qquad enq\ 1$$

where: M_f = Final moisture content, M_i = Initial moisture content and S_w = Sample weight (g)

Experimental design

Central composite design (CCD) was used for this study, based on five-levels of the three variables. The independent extrusion variables considered were die size (2-6mm), feed moisture content (12-18%) and blend composition (10 to 30%). All other parameters were kept constant. The operating ranges and five standardized levels were established after several preliminary runs as described above. All treatments were performed in a randomized order. Response Surface Methodology (RSM) and second-order CCD for three variables (Feed composition X_1, Feed moisture content X_2, and Die size X_3), five level combinations coded -1.68, -1, 0, +1, and +1.68 (Table 3). Using the coded levels, the natural levels were calculated and outlined as in Table3.2, comprising of 20 experimental runs and different formulation composition.

Table 1: Independent variables and natural levels used for central composite rotatable design

	Levels of coded variables				
Variables	**-α**	**Low**	**Centre**	**High**	**+α**
	-1.682	-1	0	+1	+1.682
Feed Composition	3.18	10	20	30	36.82
Feed Moisture	9.95	12	15	18	20.05
Die Size	2	2	4	6	6

Response surface methodology (RSM) in 3-factors (barrel temperature, moisture composition and BGN feed composition), 5-levels (-α, -1, 0, +1, +α) central composite rotatable design (CCRD) was used to formulate the blends and study the effect of the extrusion variables on the proximate and mineral compositions. Preliminary experiments results (not presented) define the variable range to lie between 100 – 140oC for extrusion barrel temperature (A), 15 – 25% feed moisture (B) and 8 – 24% BGN feed composition (C). These variables were coded to lie at ±1α for the factorial points, 0 for the centre points and ±1α for axial points. These were calculated as a function of the range of interest of each natural variable as obtained during the preliminary experiment and the coded and un-coded variables are presented in Tables 1 (coded) and 2 (un- coded). The experiments were randomized to maximize the effects of unexplained variability in the observed responses due to extraneous factors, while five replicates at the centre of the design were used to allow for estimation of pure error sum of square and lack-of-fit. One-way analysis of variance (ANOVA) was conducted ($p \leq 0.05$) to determine significant of the models and difference among the mean treatment combinations. 3D surface plots were used to visualize the relationship between dependent and independent variables using Minitab software by plotting two independent variables against a response variable, holding the third independent variable constant.

Table 2:

Run	X_1:FC	X_2: FMC	X_3:DS
***1**	10	12	2
2	30	12	2
3	20	18	2
4	30	18	2
***5**	10	12	6
6	30	12	6
7	10	18	6
8	30	18	6
9	3.18	15	4
10	36.82	15	4
11	20	9.95	4
***12**	20	20.05	4
13	10	15	4
14	15	15	2
15	15	15	2
16	30	12	6
17	10	15	4
18	10	18	6
19	20	12	4
20	15	15	2

$X_{1=}$feed composition, X_2= Moisture content, $X_{3=}$ die size,

Extrusion cooking process

The EC was performed using a co-rotating twin-screw extruder (SLG 65, Jinan Saibainuo Technology Development Company Ltd, China) powered by 16hp motor with an operating screw speed range of 0 to 300rpm, length to diameter ratio of barrel was 20:1, while the diameter of the screw was 30mm. The formulations were introduced manually into the feeding zone through a conical fed hopper at the rate of 30 kg/h while avoiding accumulation of material. When the flow was steady, samples were collected, dried and packaged before analysis.

Physical and Functional Properties

Bulk density

A graduated measuring cylinder was filled with 5g sample and gently tapped ten times on the laboratory bench until there was no space between sample particles, then volume occupied by the sample was recorded. The bulk density was expressed as described by (Filli et al., 2014).

$$Bulk\ density = \frac{weight\ of\ sample\ in\ grames}{volume\ of\ sample\ in\ mills}\ g/mL$$

Eqn.2

Expansion ratio

Expansion ratio (puff ratio) Diameter expansion is defined as the diameter of the extrudate per diameter. The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudates. The diameter of extrudates was determined as the mean of 10 random measurements made with a Vernier caliper. The extrudates expansion ratio was calculated as:

$$\boldsymbol{Expansion\ ratio = \frac{diameter\ of\ extrudate}{die\ diameter}}$$

Eqn.3

Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI were determined in triplicate following the method described by (Li & Li, 2019). Each sample (1g) suspended in 20mL of distilled water in a 45mL centrifuge tube and be stirred with glass rod then put in water bath for 30 minutes at 30°C temperature then centrifuge at 3,000r min^{-1} for 15 minutes. The supernatant would pour into dry evaporator dishes of known weight and stored overnight at 120°C for the process of evaporation. WAI and WSI would be calculating using the following equations;

$$WAI = \frac{weight\ of\ sediment}{weight\ of\ dry\ solid}, WSI = \frac{weight\ of\ dissolved\ solids\ in\ supernatant}{weight\ of\ dry\ samples\ in\ the\ original\ sample}\ x\ 100 \qquad \textbf{Eqn.4}$$

Process Optimization

A second order polynomial equation was modeled on the basis of the experimental data and optimum parameters defined using Design Expert statistical software (v.13.0.1.0, Stat-Ease Inc., Minneapolis, MN). Response variable, the coefficients of the polynomial equation (b_0, b_i and b_{ij}) are determined and the models are optimized based on the influence of the factors on the final response. The responses are expressed as second-order polynomial equation as shown on ***Eqn.5***

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

Eqn. 5

Where Y is the predicted response used as a dependent, X_1 = Feed Composition, X_2 = Feed Moisture, X_3 = Screw Speed, b_0, b_i, b_{ii}, and b_{ij} are intercepts, linear, quadratic and interaction regression coefficient terms, respectively.

RESULTS AND DISCUSSION

Bulk density

Bulk density measures the total weight per volume of the extrudes, indicating the extent of expansion. The experimental value of BD differed from 0.577 – 0.730 g/ml. Analysis of variance shown on Table 3 indicates that the linear effects of the independent variables feed composition (X_1), feed moisture content (X_2) and die size (X_3) are significant ($P<0.05$) on BD. The response model equation coefficient for BD presented in Table 4 showed a not significant lack of fit (good fit). Experimental runs (1, 12, 5) with an outlier were ignored for this analysis to be able to get a significant lack of fit(William et al., 2003). Predicted R^2 of 0.9013 which is in reasonable agreement with the Adjusted R^2 of 0.9902 due to the difference of less than 0.2 between them for BD; Adequate Precision of 39.440 is the measures of the signal to noise ratio greater than 4, which is desirable(Anderson and Whitcomb, 2007).

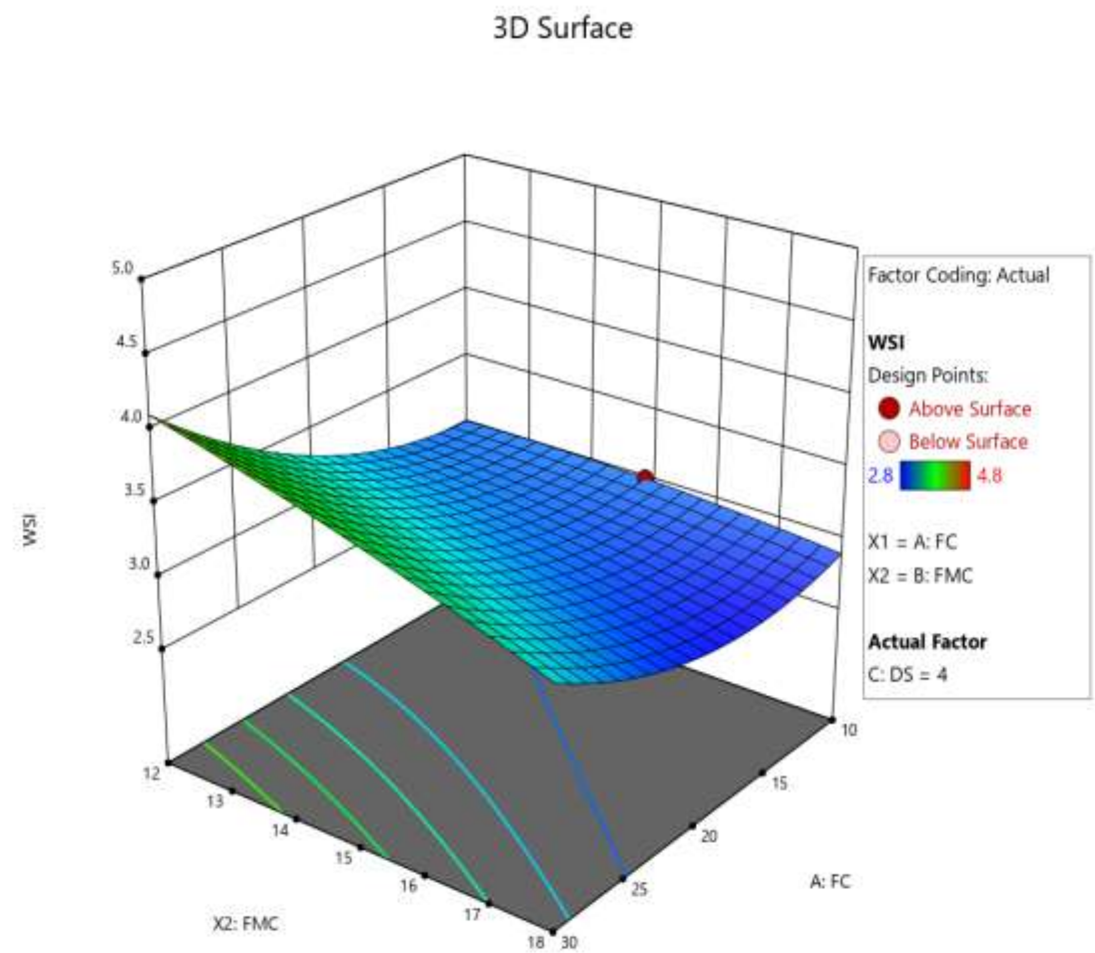
This suggests a very good fit to the experimental data and the model can be used to navigate the design process. The positive significant ($p < 0.05$) linear coefficients of X_1 and $X_{2,}$ quadratic effect X_2 and the interaction effect of X_1X_2 and X_2X_3 indicated that their effects on BD were increasing. However, the negative significant ($p < 0.05$) coefficients linear effect of X_1, quadratic effect X_1X_2 and the interaction effect of X_1X_3 resulted in a decrease in BD. However, the quadratic effect of X_2^2 and interaction effect of X_2X_3 were not significant ($p < 0.05$). The 3D surface plot and contour plot for BD (Figure 1) indicates that FC and FMC showed a significant effect on the BD, with FC having the highest effect on the BD. As percentage of FC increased with decreasing FMC, BD decrease to 0.570 g/ml while as that of FMC increases with decreasing FC a higher bulk density 0.730 g/ml was obtained(Gui & Ryu, 2014) which could be linked to lower extrudes expansion (Badrie et al., 1991;Filli et al., 2012) while DS shows least effect on the BD.

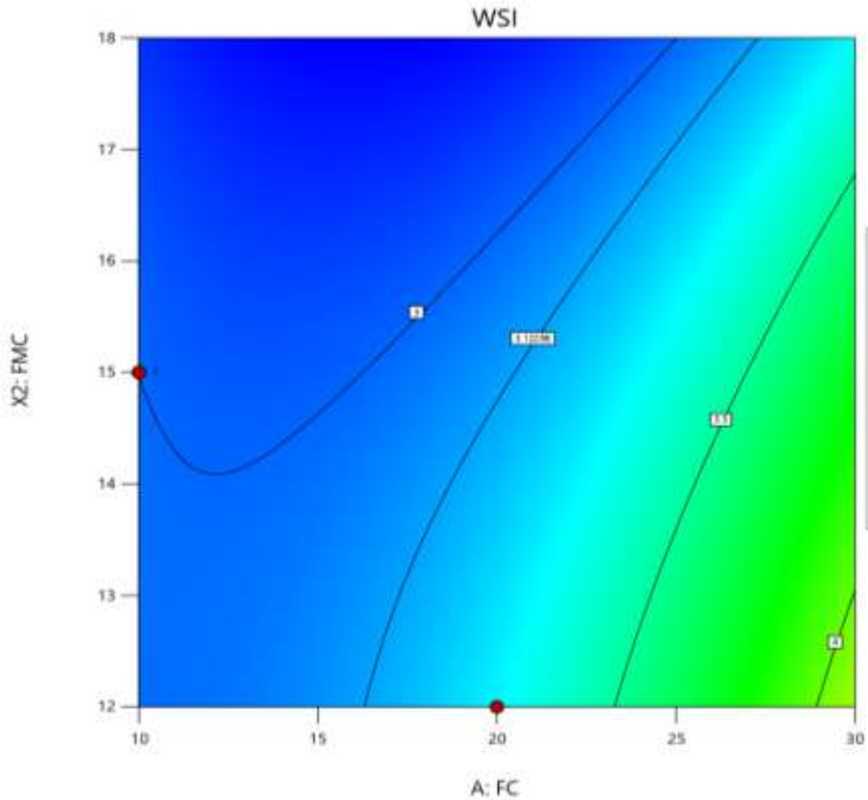
Expansion Ratio

The mean experimental values of expansion ratio ranged from 0.63 – 2.29. Analysis of variance t shown in Table 3 shows only the linear effects of the independent variables which are significant ($p < 0.05$) on the expansion ratio (ER). The response model equation coefficient for ER presented in Table 4 showed a not significant lack of fit (good fit) with a predicted R^2 of 0.50 which is in reasonable agreement with the Adjusted R^2 of 0.60 due to the difference of less than 0.2 between them for ER; Adequate Precision of 10.14 is the measures of the signal to noise ratio greater than 4, which is desirable(Anderson and whitcomb, 2007). This suggests a very good fit to the experimental data and the model can be used to navigate the design process. The negative significant ($p < 0.05$) linear coefficients of X_1 and X_2 designated that their effects on ER were declining. FMC is an important factor responsible in the mechanisms involved in expansion(Badrie et al., 1991). It is the primary plasticizer in cereal flours, allowing them to go through a glass transformation during the extrusion process, facilitating matrix deformation and expansion(Oke et al., 2013).

The 3D plot shown on Figure 1b shows that increasing FMC resulted in decreased ER with an increasing percentage of FC. The effect of FMC in many extruded foods can be explained by considering the elastic properties of the amylopectin network as being responsible for diametric expansion, which can be due to the fact that the amount of expansion in a food substance depends on the pressure difference between the die and the atmosphere; moreover, foods with lower moisture content are more viscous than those with higher moisture content, so the pressure difference is smaller for higher moisture foods, resulting in a smaller product expansion.(Filli et al., 2012). Badrie et al., (1991) reported that at a FMC of 16%, snack extrudate was soft and moist leading to poor snack extrudate expansion which can been associated to condensation of trapped steam in extrudate on cooling. In addition, Filli et al., (2012) the (Kaleb Bulus Filli et al., 2014)increase in the level of soybean flour which slightly reduced the expansion ratio of the snack extrudate, this is because of the high fat in the soybean flour. However, the result here is contrary due to the level of defatted groundnut cake used as the feed composition.

The 3D plot shown on Figure 1 shows that increasing FMC resulted in decreased ER with an increasing percentage of FC





Water absorption index (WAI) and water solubility index (WSI)

Table 3 presented the WAI and WSI of sorghums extruded with groundnut cake and date fruit flour. The ANOVA results are summarized in Table 5. The snack extrudate WAI and WSI were significantly ($p < .05$) affected by FC and FMC. The solubility of the extrudate decreases with an increase in the FC.). The WAI and WSI of the snack extrudates varied in the range of 3.00 to 5.05 g/g and 2.80 to 4.80 g/g respectively. The coefficients of the model shown on table table 5 shows that the Model F-value of 13.61 and 12.59 implies that the models are significant ($P < 0.05$) respectively, with only a 0.02% chance that an F-value this large could occur due to noise.

The coefficient of determination R2 observed were 0.93 and 0.92 for WAI and WSI respectively with a non-significant ($P > 0.05$) lack of fit for both WAI and WSI, suggesting a good fit of the regression model. The Adequate Precision value of 12.13 and 11.97 respectively implies that the model can be used for prediction purposes. It can be seen from table 5 that the coefficients of X_2, X_3 are negative, however, that of X_1 is positive; therefore, increase in FMC and DS content may reduce the water absorption index, whereas increase in FC increase the water absorption index, this corresponds to the research of Filli et al., (2013) that reported the increasing FC level of Bambara groundnut flour was found to increase the WSI due to non-covalent interactions between polypeptide chains of and other constituents, as well as the forming of new disulfide bonds, were responsible for the rise in water absorption as a result of high protein content (20 - 22%) in the raw material that was used. It was also observed that the linear coefficient of X_1 and X_3 are positive while that of X_2 is negative for WSI, these also implies that increase in FC and DS increase the WSI while the increase in FMC reduced the WSI, this is in line with the review of Jiangping et al. (2017) that describes WAI and WSI of extrudates depend on the extrusion processing conditions FMC, which serves as a plasticizer, perhaps reduces shearing and starch degradation during extrusion, therefore high FMC results in higher WAI.

Oil absorption index

The mechanism of oil absorption is attributed mainly to the physical entrapment of oil and the binding of fat to the apolar chain of protein (Abiona et al., 2018). The oil absorption index from Table 4 varied from 0.20 to 0.38ml/g. The Model F-value of 14.32 implies the model is significant showing only a 0.01% chance that an F-value this large could occur due to noise. In this case X_1, X_2, X_1^2 and X_3^2 are significant model terms ($P<0.05$). While case X_3, X_2^2, X_3^2, X_1X_2, X_2X_3 and X_1X_3 indicate the model terms are not significant ($P<0.05$). The Lack of Fit F-value of 1.59 implies the Lack of Fit is not significant ($P>0.05$) relative to the pure error. There is a 31.25% chance that a Lack of Fit F-value this large could occur due to noise. The result indicated that the increase in FC increased the oil absorption index with a slight increase FMC. Food product that absorbed oil increases mouth feel and taste retention. As compared to hydrophilic groups on the surface of protein molecules, high oil absorption ability could indicate the existence of a large proportion of hydrophobic groups(Jav et al., 2019).

Table 3: Physiochemical Properties

	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3	Response 4	Response 5
Run	X_1:FC	X_2: FMC	X_3:DS	BD	WAI	WSI	ER	OAI
***1**	10	12	2	0.7000	3.60	3.3	2.29	0.29
2	30	12	2	0.590	4.40	4.1	1.92	0.33
3	20	18	2	0.700	3.23	3.0	0.73	0.24
4	30	18	2	0.670	3.47	3.2	0.63	0.26
***5**	10	12	6	0.702	3.65	3.4	1.92	0.28
6	30	12	6	0.590	4.45	4.2	1.85	0.35
7	10	18	6	0.730	3.00	2.9	1.53	0.21

8	30	18	6	0.670	3.57	3.4	1.38	0.28
9	3.18	15	4	0.700	3.25	3.0	2.04	0.24
10	36.82	15	4	0.570	5.05	4.8	1.24	0.38
11	20	9.95	4	0.679	3.56	3.3	1.92	0.27
***12**	20	20.05	4	0.712	3.00	2.8	1.07	0.2
13	10	15	4	0.719	3.10	3.0	1.19	0.25
14	15	15	2	0.679	3.54	3.3	1.06	0.28
15	15	15	2	0.681	3.47	3.2	1.74	0.26
16	30	12	6	0.577	5.00	4.7	1.84	0.37
17	10	15	4	0.719	3.15	3.0	1.74	0.24
18	10	18	6	0.735	3.05	3.0	1.74	0.25
19	20	12	4	0.691	3.30	3.1	1.72	0.25
20	15	15	2	0.670	3.50	3.3	1.7	0.27

$X_{1=}$feed composition, X_2= Moisture content, $X_{3=}$ die size, BD=Bulk density, WAI=Water absorption index, WSI= Water solubility index, ER=Expansion ratio, OAI= Oil Water absorption index

Table 5: Coefficient of Polynomial Models & ANOVA of Physiochemical Properties Contents of Snack

Source	BD Coeff. eqn.	F-v	p-v	WAI Coeff. eqn.	F-v	p-v	WSI Coeff. eqn.	F-v	p-v	ER Coeff. eqn.	F-v	p-v	OAI Coeff. eqn.	F-v	p-v	
Model	Quadra	181.33	0.0001	Quadra	13.61	0.0002	Quadra	12.59	0.0002	linear	10.22	0.0005	Quadra	14.32	0.0001	S
	0.7067			-0.2641			3.10			1.53			0.2488			
X_1-FC	-0.0375	362.09	0.0001	-0.1663	33.75	0.0002	0.3783	34.14	0.0002	-0.1702	6.09	0.0253	0.0291	32.44	0.0002	
X_2-fmc	0.0217	32.00	0.0008	-0.0857	18.90	0.0015	-0.2308	15.31	0.0029	-0.3360	23.08	0.0002	-0.0247	28.06	0.0003	
X_3-DS	0.0135	16.99	0.0044	-0.0313	0.1569	0.7004	0.0218	0.081	0.7818	0.1390	3.09	0.0979	0.0010	0.0282	0.8699	
X_1X_2	0.0203	20.59	0.0027	-0.0007	3.72	0.0826	-0.1734	4.29	0.0651				-0.0077	1.37	0.2693	
X_1X_3	-0.0152	15.25	0.0059	0.1217	2.10	0.1780	0.1002	1.51	0.2471				0.0105	2.69	0.1323	
X_2X_3	0.0006	0.0798	0.7857	0.2328	1.15	0.3087	-0.0551	0.505	0.4935				-0.0022	0.1315	0.7244	
X_1^2	-0.0253	101.72	0.0001	0.3230	11.56	0.0068	0.2742	8.85	0.0139				0.0217	8.87	0.0139	

X_2^2	0.0038	1.23	0.3035	0.3876	0.0001	0.9940	-0.0446	0.256	0.6239				-0.0066	0.8928	0.3670	
X_3^2	-0.0202	13.59	0.0078	3.21	3.72	0.0828	0.1874	2.56	0.1409				0.0225	5.93	0.0351	
Lof			0.6330		2.53	0.1661		2.75	0.1454		0.812	0.6423		1.59	0.3125	N
R^2	0.9957			0.9245			0.9189			0.6570			0.9280			
Adj R^2	0.9902			0.8566			0.8459			0.5927			0.8632			
Pred R^2	0.9013			0.3574			0.3048			0.4832			0.4749			
Adq Press	39.4400			12.1267			11.9649			10.1438			13.6127			

X_1-FC = feed composition, X_2-MC = moisture content, X_3-DS = die size, Adj=adjusted, Pred R^2 = Predicted R^2, p-v **= p-values, F-v = F-values,** Coeff. Eqn= Coefficient equation, **R**quadra = Reduced Quadratic, Quadra = Quadratic, S=Significant, N=Not-significant

Process Optimization

Design Expert statistical software Response Optimizer was used for the optimization of the multiple response variables, to examine the optimum combination of independent variables points that meet the goal requirement for each factor at the same time. Danbaba et al., (2018) proposed that for numerical optimization, the following goals option were to be selected: None, Maximum, Minimum, Target, or Range for the independent variables and response should be set, with all goals combining into one desirable feature. The independent variables in this analysis are sets of parameters that will satisfy all of the objectives (i) FC (10-30%), (ii) FMC (12-18%) and (iii) DS (2-6 mm) with an 'importance' score of a goal within 1 to 5 and setting goal importance at 3, indicating the variable to be considered are equally important. The optimum independent variables were found to be 23.75% FC, 13.43% FMC, 6.0 mm DS with the dispensability 0.50, which produces 0.66 BD, 3.86 WAI, 3.70 WSI, 1.78 ER, and 0.30 OAI. These results indicated that optimum values can be obtained in the extrusion of snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the development of post covid-19 snack food.

CONCLUSION

The study evaluate the effect of extrusion cooking on physicochemical properties of an extruded snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the development of post covid-19 snack food. Various conditions of feed composition (FC), feed moisture content (FMC), and die size (DS) were studied.

The results of physiochemical properties of the products showed a relation between bulk density and expansion ratio of extruded materials i.e., the greater the expansion volume, the lower the bulk density. The optimum independent variables conditions were found to be 23.75% FC, 13.43% FMC, 6.0 mm DS with the dispensability 0.50, which produces 0.66 BD, 3.86 WAI, 3.70 WSI, 1.78 ER, and 0.30 OAI. The results also indicated that optimum values can be obtained in the extrusion of snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the development of post covid-19 snack food

RECOMMENDATIONS

i. The optimum independent variables conditions were found to be 23.75% FC, 13.43% FMC, 6.0 mm DS with the dispensability 0.50, which produces 0.66 BD, 3.86 WAI, 3.70 WSI, 1.78 ER, and 0.30 OAI

ii. It could be recommended that; optimum value that shows a good physical and functional behavior at a desirability of 50% can be obtained in the extrusion of snack from the blend of sorghum and groundnut cake flour enriched with date fruit flour for the development of post covid-19 snack food.

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