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Effect of paddy storage and processing parameters on quality of *Ofada* rice in the production of ready to eat flakes

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Effect of paddy storage duration and processing parameters (soaking time, parboiling temperature and drying temperature) were optimized using response surface methodology for the production of ready to eat *Ofada* rice flakes which serves as alternative mean of harnessing its potential. There exist significance differences at p<0.05 for all the parameters except carbohydrate and metabolizable energy. The quadratic models were fit for prediction of effect of storage and processing parameters on quality of flakes produced from ofada paddy. The R^2 ranged from 0.9662 to 0.7318 which confirmed the fitness of the model. The predicted and validated values were related. The optimum storage duration and processing parameters for treatment of *Ofada* paddy in the production of ready to eat flake include storage of paddy for 9 months, soaking for 4 days and 17 h, parboiling at 106°C and drying at 30°C to yield optimum quality of *Ofada* rice flakes. The sensory assessment showed significant acceptability of colour, crispiness, aroma, taste and overall acceptability.

Key words: Ofada, processing parameters, response surface methodology, ready-to-eat flakes, optimization.

INTRODUCTION

Rice (Oryza sativa L) is enjoyed by many people as staple food especially varieties with distinctive aroma and flavor (Bryant and McChung, 2011). One of the popular indigenous rice varieties in Nigeria is *Ofada* rice. "*Ofada*" is a generic name used to describe all rice produced and processed in South-West, Nigeria. One of the early cultivated variety is OS6 and it is relished because of is aroma (NCRI and WARDA, 2007). Rice produced in Nigeria is consumed mostly in the form of boiled rice and as mashed porridge rolled into round balls both eaten with soup.

Nowadays, ready-to-eat foods are gaining much importance as they are convenient to use, easy to handle compared with ready-to-cook foods (Itasi et al., 2012). There is few or no utilisation of Nigeria rice flour in pastry production, however, production of breakfast cereals from maize, sorghum, millet is common. The use of rice for preparation of breakfast cereal such as noodles, flakes is

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Table 1. Independent variables and levels.

Variables	Levels		
Storage duration (months)	1	5	9
Soaking time (days)	1	3	5
Parboiling temperature (°C)	80	100	120
Drying temperature (°C)	30	50	70

common in United States and Europe, therefore, utilization of Nigeria local rice for ready-to-eat flakes is another way of harnessing the potential of local rice. The aromatic characteristic, taste and immense nutritive value of *ofada* rice (OS6) compare to other local varieties are potentials that worth to be investigated in the production of high quality *ofada* ready-to-eat flakes.

According to Fred (2007), processing conditions of grain in flakes production could affect the quality of flakes. The major traditional unit operations in paddy processing include soaking, parboiling, and drying. The effects of storage history and ageing on rice were also documented (Zhou et al., 2001; Daniel et al., 1998). Therefore, the storage duration and processing conditions of paddy into rice flour for the production flake may have effect on quality of flake. Response surface methodology (RSM) is important in designing experiment, formulating, developing and analysing new and existing scientific studies cutting the cost, and measures several effects by objective test (Akinoso and Adeyanju, 2010; Montgomery, 2005). The main objective of the study was to optimize paddy storage duration and processing parameters (soaking time, parboiling temperature and drying temperature) of ofada paddy using response surface methodology for the production of quality ready-to-eat ofada rice flakes. The results of this study will make relevant technical data available for the present and prospective investors that would have relied on “trial and error” method in processing *ofada* rice and its utilisation for flake production. This will help to make the local rice sufficiently more competitive thereby increasing its demand.

MATERIALS AND METHODS

Ofada paddy (OS 6) was purchased at farm gate in Mokolokin-Ofada, a renowned area for *Ofada* rice production. The processing unit operations (soaking, parboiling, drying) used as treatment was adopted from the methods of processing of paddy adopted by the rice farmers in the area. D- Optimal response surface methodology was used for the design of the experiment. The independent and levels of variables is shown in Table 1. The rice stalk was threshed manually and cleaned to obtain paddy within 12 h, mixed thoroughly and stored in a dry cool place for processing at 1, 5 and 9 months as described in the experimental design.

Paddy (4kg) was soaked in cold water at ambient temperature (28±2°C) for typically 1, 3 and 5 day(s) to hydrate the kernels. The soaked paddy were parboiled at varied temperatures (80, 100, and 120°C) at constant pressure using digital autoclave for 15 min. The parboiled paddy were tempered for 30 min to cool and air dried in oven at 30, 50 and 70°C. The rice samples were milled (hulling and debranning) in grantex cono disc milling machine. The rice obtained were subsequently ground in a hammer mill, sieved (200 micron size) and analysed.

Production of *Ofada* rice flakes

The laboratory production of ready-to-eat flakes was carried out as described by Lu and Walker (1988). The milled rice was cleaned and ground into flour. The flour was sifted with sieve (60-mesh testing sieve) and the coarse residues were discarded. Flour (400 g) was mixed with 300 ml of water, 25 g of sugar, and 4 g of salt in a kitchen Kenwood mixer for 5 min. The dough was placed in a pasta extruder attachment and forced through a die with 5-mm hole. After the extrusion, it was cut 0.5 cm long pellets, and steamed using a pressure cooker for 15 min. After cooking, the pellets were tempered and pressed through a heavily spring roller. The resulting flakes were toasted on pans at 200°C for 20 min, cooled, and packaged in plastic.

Analysis of rice flakes

The analysis carried out on flakes include moisture, crude protein, crude fat, and ash contents, using AOAC,(2000); carbohydrates by difference and metabolizable energy by FAO (2002); phytic acid was carried out as described by Garcia-Estepa et al. (1999) and water absorption capacity as described by Walker et al. (1988).

RESULTS AND DISCUSSION

The result of chemical and functional qualities of ready-to-eat *ofada* rice flakes as affected by storage and processing parameters of *ofada* rice paddy is presented (Table 2).

Moisture composition of ready to eat *ofada* rice flakes

There were significant differences in the result of moisture contents obtained at $p < 0.05$. The minimum and maximum moisture content of the rice flakes were 3.10 and 6.89 respectively (Table 2). The least percentage moisture content was obtained from flake produced from *Ofada* paddy stored for 9 months and subjected to processing operations which involved 5 days of soaking, 80°C parboiling, and 30°C drying temperature while the maximum moisture in the flake was obtained from the paddy stored for 1 month, soaked for 1 day, parboiled at 120°C, and dried at 30°C temperature.

The R^2, adjusted R^2, and adequate precision are presented in Table 3 and coefficient of the model depicting effect of processing conditions of paddy and storage duration in the production of rice flour for the manufacturing of flakes is presented in Table 4. Positive coefficient of drying temperature showed that drying process of paddy has a major influence on moisture content of flake. The movement of water out of the flake during drying and into the flake during food processing (water absorption) has implications on quality (Fred, 2007).

Table 2. Result of chemical and functional composition of Ofada rice flakes.

Number	Soaking time (day)	Parboiling temp. (°C)	Drying Temp. (°C)	Storage Duration	Moisture (%)	Protein (%)	Ether extract (%)	Ash (%)	Carbohydrate (%)	Phytate (%)	Water absorption ratio	Metabolisable Energy (kcal/100 g)
1	5	120	70	1	5.9	8.5	0.89	2.93	81.78	0.8	2.37	368.46
2	1	80	70	1	5.6	8.81	1.49	2.4	81.7	1.51	3.43	374.81
3	1	80	30	5	6.25	9.73	0.3	1.28	82.44	1.47	4.34	382.63
4	5	80	30	1	5.6	8.77	0.49	1.57	83.57	0.69	2.65	373.03
5	5	80	30	9	5.65	12.84	0.49	1.59	79.43	1.15	4.29	383.53
6	3	80	50	5	5.15	10.26	0.52	0.95	83.12	1.46	4.77	389.33
7	5	120	30	5	5.4	9.64	0.4	0.2	84.36	0.39	4.51	391.11
8	1	80	70	1	5.69	8.9	0.97	2.43	82.01	1.36	3.41	371.67
9	5	120	70	9	5.75	12.21	0.51	1.68	79.85	0.51	4.41	383.09
10	3	120	50	5	5.85	10.5	0.37	1.13	82.15	0.62	4.17	384.95
11	3	120	30	9	3.7	13.1	0.66	1.6	80.94	0.92	4.55	392.28
12	5	100	50	5	5.25	10.19	0.31	1.03	83.22	0.64	4.69	387.72
13	1	120	70	5	5.1	9.76	0.24	1.03	83.87	1.01	4.88	388.19
14	3	100	50	9	3.73	13.01	0.76	1.72	80.76	1.09	4.74	392.02
15	1	120	50	9	5.6	12.81	0.32	1.52	79.75	1.14	4.32	383.37
16	5	120	70	1	5.24	8.62	0.86	2.94	82.34	0.72	2.38	370.89
17	1	100	50	5	5.3	9.96	0.46	1.12	83.16	1.36	4.59	387.84
18	3	100	50	5	4.05	6.99	0.46	2.63	86.87	0.89	2.95	378.99
19	5	80	30	1	5.01	8.81	0.56	1.65	83.97	0.71	2.67	375.42
20	1	120	30	1	6.89	9.36	0.63	1.42	85.79	1.42	3.22	385.49
21	1	100	30	9	3.33	12.76	0.44	1.74	81.73	1.53	4.52	392.42
22	5	80	70	5	6.85	9.94	0.43	1.01	81.77	1.42	4.66	381.73
23	1	80	70	9	3.8	12.93	0.52	2.05	80.7	1.67	4.21	389.46
24	5	80	30	9	3.1	12.61	0.38	1.65	82.26	1.22	3.92	393.55
25	1	120	30	1	6.82	9.28	0.67	1.41	81.82	1.25	3.24	369.66

Flake thickness influences the rate of diffusion of water during drying. However, Machado et al. (1998) reported that range of thickness did not correlate with water absorption.

Oeding (1996) has profound that higher steam temperature and great moisture during steaming resulted in increased water absorption, and also suggested that this was related to changes in pasting behaviour. The report justified the result of this experiment with rice parboiled at highest temperature measuring highest percentage of moisture while this decreased with reduction in parboiled temperature.

Protein composition of ready-to-eat *ofada* rice flakes

The results of the protein content of rice flakes ranged between 6.99 to 13.10 % (Table 2). Some of the values obtained in this study were comparable to protein content of flake made from wheat (USDA, 2013). There exist significant differences in the result for protein at $p < 0.05$ and values of R^2, adjusted R^2, and adequate precision are presented in Table 3. The closeness of R^2 and Adjusted R^2 to 1 and extent of greatness of adequate precision above 4 were indicators of the

Table 3. ANOVA of regression of chemical and functional qualities of Ofada rice flakes.

Parameters	p-value	R^2	Adjusted R^2	Adequate precision
Moisture (%)	0.0207	0.84	0.6161	7.088
Protein (%)	0.0019	0.9084	0.7802	7.58
Ether extract (%)	0.0029	0.8991	0.7579	9.795
Ash (%)	0.0267	0.8297	0.5914	7.966
Carbohydrate (%)	0.146	0.7318	0.3562	5.317
Phytate (%)	<0.0001	0.9662	0.919	16.673
Water absorption ratio	0.0229	0.8361	0.6066	5.835
Metabolisable energy (kcal/100 g)	0.0627	0.7882	0.4917	5.013

Table 4. Coefficient of the quadratic model for the effect of storage and processing parameters on ofada rice quality in production of ready to eat flakes.

Parameter	Moisture (%)	Protein (%)	Ether extract (%)	Ash (%)	CHO (%)	Phytate (%)	Water absorbtion	M.E (kcal/100 g)
Intercept	36.41	23.04	-0.76	-4.27	38.55	2.77	3.56	296.21
S	-2.31	-0.65	-0.02	0.42	2.9	-0.12	-0.45	3.72
P	-0.66	-0.37	0.03	0.16	1.01	-0.03	-0.03	1.44
D	0.21	0.19	0.03	-0.06	-0.39	0.01	0.04	-0.21
T	-0.27	-0.09	-0.24	-0.34	0.79	0.18	0.48	5.86
S^2	0.28	0.12	-0.03	-0.12	-0.3	$6.30X10^{-3}$	0.08	-0.27
P^2	$3.33x10^{-3}$	$2.02x10^{-3}$	$-1.44x10^{-4}$	$-9.17x10^{-4}$	$-4.89x10^{-3}$	$2.17x10^{-4}$	$2.19x10^{-4}$	$-5.92x10^{-3}$
D^2	$-2.30x10^{-3}$	$-1.45X10^{-3}$	$-1.55X10^{-5}$	$3.42X10^{-4}$	$3.68X10^{-3}$	$2.97X10^{-5}$	$-3.32X10^{-6}$	$5.65X10^{-3}$
T^2	-0.03	0.07	0.02	0.06	-0.11	$3.38X10^{-3}$	-0.05	-0.32
SP	$-2.63X10^{-3}$	$-1.63X10^{-3}$	$1.87X10^{-3}$	$2.62X10^{-3}$	$-3.99X10^{-3}$	$-2.11X10^{-3}$	$-1.75X10^{-3}$	$-1.44X10^{-3}$
SP	6.01	$2.12X10^{-3}$	$-1.55X10^{-4}$	$1.19X10^{-3}$	-0.01	$3.40X10^{-3}$	$7.94X10^{-4}$	-0.04
ST	0.04	$-6.07X10^{-3}$	$8.27X10^{-3}$	$-8.16X10^{-3}$	$-7.57X10^{-3}$	$-1.30X10^{-3}$	0.02	$5.19X10^{-3}$
PD	$-3.18X10^{-4}$	$-5.50X10^{-4}$	$-1.47X10^{-4}$	$4.73X10^{-4}$	$2.29X10^{-4}$	$-2.03X10^{-4}$	$-3.98X10^{-4}$	$-3.26X10^{-3}$
PT	$1.98X10^{-3}$	$-5.35X10^{-4}$	$2.42X10^{-4}$	$-1.50X10^{-3}$	$-3.28X10^{-3}$	$-1.43X10^{-3}$	$1.95X10^{-3}$	-0.01
DT	$1.81X10^{-3}$	$-9.5X10^{-4}$	$-1.06X10^{-3}$	$-2.08X10^{-3}$	$5.53X10^{-3}$	$-9.09X10^{-4}$	$-3.65X10^{-4}$	$3.95X10^{-3}$

S,soaking time; P, parboiling temp.; D,drying temp.; T, storage duration.

degree of fitness of the model. The coefficients of the model are presented in Table 4. Maximum protein content in rice flake was obtained from paddy stored for 9 months, and subjected to 3 days soaking, 100°C parboiling temperature, and 50°C drying temperature. It was revealed that ready-to-eat *Ofada* rice flakes produced from paddy stored for longer duration relatively shown improvement in protein content (Table 2).

The protein composition recorded in this experiment was higher than the result as reported by Nazni and Bhuvaneswari, (2011), and also higher than the nutritional protein composition of the popular 'Kelloggs' products.

Fat composition of ready to eat *ofada* rice flakes

The results of crude fat were significant at $p < 0.05$ and ranged from 0.24 to 1.49% with mean value of 0.57%. Generally, the crude fat contents were low (<1.5 %) with the maximum extract recorded from the flake produced from paddy stored for 1 month and treated under 1 day soaking, 80°C parboiling and 70°C drying temperatures respectively while the minimum value was from rice stored for 5 months, and processed by soaking for 1 day, parboiling at 120°C and drying temperature at 70°C. The coefficient of the model was presented (Table 4). The result obtained from this experiment is comparable to the general fat content recorded for most commercial rice flakes (Fatsecret, 2013). High fat content can easily cause rancidity of the package foods, however, maximum of 3% fat has been found in most commercial rice flakes. Gupta et al. (2012), recorded fat content range of 0.76 – 5.91 % in the production of rice flakes mix using dehydrated herbs.

Ash contents of ready to eat rice flakes

The ash content is the total mineral composition of rice flakes and it ranged from 0.20 to 2.94 %. Maximum ash content was from rice flake produced from the paddy stored for 1 month followed by soaking of the rough rice for 5 days, parboiling at 120°C, and drying at 70°C while minimum value was obtained from rice stored for 5 months, soaked for 5 months, parboiled for 120°C and dried at 30°C drying temperature. It was observed that the effect of storage duration and drying temperature could have been responsible for the variation. The coefficient of the model revealed that soaking time and parboiling temperature treatment were major indicators of the ash contents of the flakes (Table 4). The milling operation might affect ash content of the flakes due to the presence of bran.

Carbohydrate contents of ready to eat *ofada* rice flakes

There was no significant difference (p>0.05) in the data obtained for carbohydrate. The carbohydrate contents ranged from 79.43 – 86.87% and "Lack of Fit test" is not significant which revealed that such model can still be used in prediction. The values of R^2, Adjusted R^2, and adequate precision of the model were presented in Table 3. The report has shown that storage duration of paddy and processing conditions of ofada rice does not have significant influence on the carbohydrate content of ready to eat rice flakes.

Water absorption of ready-to-eat *ofada* rice flakes

Water absorption is one of the major factors in determining the quality of flakes. The results obtained ranged from 2.37-4.88 and there were significant differences in the water absorption ratio values of the rice flakes (p<0.05). Observation of the data revealed that the rate of water absorption majorly varied with the storage duration of paddy before processing. However, the highest water absorption ratio was obtained in rice flakes processed from rice subjected to 1 day soaking, 120^0C parboiling temperature, 70^0C drying after storage for 5 months duration. However, values of R^2, Adjusted R^2, and adequate precision were presented (Table 3). The coefficient of the model showed a positive influence of drying temperature (D) and storage duration (T) on raw material processing (paddy) in manufacturing of flakes (Table 4).

Phytate composition of ready-to-eat *ofada* flakes

Rice contains some important anti-nutritional factors, most which are concentrated in the bran. All anti nutritional factors in rice except phytate are proteins and denatured by heat. The phytate levels from the experiment ranged from 0.39-1.67%. Variation in respect of phytate content was found to be significant (p < 0.05). The highest amount of phytate was recorded in the flake produced from rice stored for 9 months, processed by soaking for 1 day, 80°C parboiling temperature, and 70°C drying temperature while the least value of phytate was at 5 days soaking, 120°C parboiling, 30°C drying and 5 months storage duration of paddy. According to Noreen et al. (2009), soaking and boiling processes caused significant decrease in phytic acid in rice. This report may be related to the reason why soaking at longest day and highest degree of parboiling temperature resulted to the least value of phytate while the opposite of the processing conditions in terms of soaking and parboiling gave the highest phytate value in the rice flake. Humans have limited ability to absorb and hydrolyse phytate (Pawar and Ingle, 1988). Binding of minerals with phytic acid decrease bio availability of calcium, iron, phosphorus, zinc and other trace elements to human and other monogastric animals. This may lead to severe nutritional and consequently health problems in the consuming population (Thompson (1987).

Metabolization energy of ready to eat *ofada* rice flakes

The metabolizable energy in the flakes was between 368.46-393.55 kcal/100 g. There exist no significant difference (P > 0.05) in the metabolizable energy obtained from the rice flakes as affected by the processing condition and storage duration of paddy before processing. The R^2 and Adjusted R^2 were 0.7882 and 0.4917 respectively (Table 3).

Optimisation and validation of chemical quality of ready-to-eat *ofada* rice flakes

The optimisation of the ready to eat *ofada* rice flake was based on quality indices and level of desirability expected from high profile ready-to-eat flakes. These indices include maximum protein for good nutrition, minimum fat to prevent rancidity, minimum moisture to increase its shelf life and to prevent microbial activities, maximum ash represents total mineral composition which is also vital in nutrition because of their various functions, carbohydrate was not specified since the product have high carbohydrate value, minimum phytate (antinutritional factor usually found in rice), maximum metabolizable energy and maximum water absorption.

There were ten solutions suggested with desirability range of 0.745 to 0.783 with the first predicted solution having the highest desirability (Table 5). This involved storage of paddy for 9 months, soaking for 4 days and 17 h, parboiling at 106°C and drying at 30°C before milling to flour of desired particle size for the production of ready to

Table 5. Result of optimisation of quality of Ofada rice flakes.

S/N	Soaking Time (day)	Parboiling temp.	Drying Temp.	Storage Duration	Moisture (%)	Protein (%)	Ether extract (%)	Ash (%)	Phytate %	Water absorption ratio	Metabolisable Energy (kcal/100 g)	Desirebility
1	4.70	106.16	30.00	9.00	3.1	12.164	0.67	1.621	0.665	4.4035	393.192	0.7832
2	4.75	105.32	30.00	8.99	3.099	12.148	0.663	1.619	0.67	4.40266	393.191	0.7831
3	4.62	107.24	30.07	9.00	3.099	12.178	0.678	1.63	0.664	4.40116	393.166	0.7829
4	4.79	103.94	30.13	9.00	3.102	12.144	0.654	1.63	0.685	4.39364	393.112	0.7824
5	4.90	99.66	30.01	9.00	3.099	12.123	0.623	1.651	0.743	4.36695	392.962	0.7787
6	1.94	114.80	70.00	9.00	3.1	11.818	0.466	2.183	0.881	4.21874	388.686	0.7774
7	2.06	114.92	70.00	9.00	3.1	11.793	0.479	2.207	0.866	4.20355	388.584	0.7773
8	1.92	114.76	70.00	9.00	3.099	11.816	0.463	2.178	0.883	4.22206	388.71	0.7773
9	1.91	114.54	70.00	8.93	3.099	11.745	0.458	2.178	0.887	4.23492	388.817	0.7773
10	3.64	113.71	30.00	8.95	3.1	12.269	0.698	2.178	0.786	4.37523	392.861	0.7773

Table 6. Result of sensory evaluation of *ofada* rice flakes.

Ofada rice flakes	Colour	Taste	Aroma	Crispiness	Overall acceptability
First solution	6.7a	7.1a	6.9a	6a	7.30a
Sixth solution	6.3a	7.5a	7.2a	6.3a	6.4b
Tenth solution	7.8b	7.20a	6.80a	6.2a	6.6a

eat flakes to yield 3.10% moisture, 12.16% protein, 0.67% ether extract, 1.62% ash, 393.19 kcal/100 g, 0.67% phytate, and 4.40 water absorption ratio. However, the first three solutions as presented (Table 5) have similar desirability with high closeness of processing conditions and the same storage duration of paddy. Observations of the yields were also closely related.

The result of the validation of the best predicted solution showed yields of 4.08% moisture, 11.93% protein, 0.86% ether extract, 1.92% ash, 81.21%, 390.60 kcal/kg, 4.57 water absorption and 0.32% phytate. However, the results of the validation are closer to the result predicted by the response surface.

Sensory evaluation of ready-to-eat *ofada* rice flakes

The first, sixth and tenth predicted solutions were chosen for sensory evaluation based on variation of the levels of processing conditions. The ready to eat Ofada rice flakes manufactured were subjected to sensory analysis (colour, crispiness, taste, aroma, and overall acceptability) based on a nine point hedonic scale, where 1 is dislike extremely and 9 is like extremely. The result of the sensory analysis is presented in Table 6.

There exist no significant differences in crispiness, taste, and aroma, however, significant difference was shown in colour attribute with flakes produced from tenth predicted solution been rated better than the two. For the overall acceptability, the first solution was most accepted.

Conclusion

The effect of paddy storage duration and processing parameters (soaking time, parboiling temperature and drying temperature) were optimized for the production of ready to eat of ofada rice flakes. The coefficient of the model shown that soaking time of paddy has positive influence on ash, carbo-hydrate and metabolisable energy of rice flakes; parboiling temperature was positive on ether extract, ash, carbohydrate and metabolisable energy; drying temperature of paddy gave positive influence on moisture, protein, ether extract, phytate, metabolisable aenergy and water absorption; storage duration of ofada paddy also influence carbohydrate, phytate, water absorption, and metabolisable energy. The R^2 ranged from 0.9662 to 0.7318 which confirmed the fitness of the model. The optimum storage duration and processing parameters for treatment of ofada paddy for the production of ready to eat flake include storage of paddy for 9 months, soaking for 4 days and 17 h, parboiling at 106°C and drying at 30°C to yield optimum quality of ofada rice flakes. The sensory assessment showed good acceptability, colour, crispiness, aroma and taste.

Conflict of interests

The author(s) did not declare any conflict of interest.

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