Journal of Food Technology Research
2020 Vol. 7, No. 1, pp. 48-58
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/journal.58.2020.71.48.58

MODELLING AND OPTIMIZATION OF RICE (Oryza sativa L.) PADDY PRE-TREATMENTS FOR OPTIMUM CHEMICAL PROPERTY USING RESPONSE SURFACE METHODOLOGY

Osunrinade Oludolapo A.[1+]
Akinoso R.[2]

[1,2]*Department of Food Technology, University of Ibadan, Ibadan, Nigeria.*
[1]*Email: dolaps2004@yahoo.com Tel: +2348162592121*
[2]*Email: akinoso2002@yahoo.com Tel: +2348023885622*

(+ Corresponding author)

Article History
Received: 29 November 2019
Revised: 7 January 2019
Accepted: 13 February 2020
Published: 9 March 2020

Keywords
Rice
Amylose
Soaking
Parboiling
Proximate
Pre-treatment
Optimisation.

ABSTRACT

Rice (*Oryza sativa L.* variety OS-6) paddy pre-treatments condition was optimized with respect to proximate, amylose and free fatty acids (FFA) composition. Soaking duration (1, 3 and 5 days), initial soaking temperature (30, 65 and 100 ^{0}C), parboiling temperature (80, 100 and 120 ^{0}C) and drying temperature (30, 50 and 70 ^{0}C) were used as independent factors in D-optimal response surface design methodology. AOAC methods were used for determination of proximate and free fatty acid composition. Amylose content was determined using standard method. Moisture, ash, fat, protein, crude fibre, carbohydrate, amylose contents and FFA of the rice were 4.22- 10.24%, 0.24-0.71%, 0.62-1.73%, 7.41-9.57%, 0.60-1.71%, 78.31-84.65%, 17.41-22.34% 25 and 0.70-3.80%, respectively. The R^2 for the model fitted ranged from 0.457 to 0.922. The range of R^2 and p-value obtained for moisture, carbohydrate, energy, FFA and amylose affirms the degree of fitness of models obtained. The optimum rice paddy pre-treatment condition obtained was 1 day: 4.8 minutes, initial soaking temperature of 35 ^{o}C, Parboiling temperature of 98.03 ^{o}C and drying temperature of 70 ^{o}C.

Contribution/Originality: This study provided detailed changes that occur in the chemical properties of rice (*Oryza sativa L.* variety OS-6) as affected by paddy pre-treatments. Effect of variation in pre-treatment conditions was reported, while processing conditions for optimum chemical composition of rice was also established.

1. INTRODUCTION

Rice being one of the most important cereals of the world is widely consumed and cultivated in most countries. *Oryza glaberrima Steud* and *O. sativa* L. are the cultivated species in Nigeria (Abulude, 2004; Adeyemi, Fagade, & Ayotade, 1986). Rice variety OS-6 being one of the earliest released Ofada rice can be described as a short grain robust rice (National Cereal Research Institute (NCRI) & Africa Rice Centre (WARDA), 2007). Ofada is a generic name used to describe all rice produced and processed in the rice producing clusters of the South-West Nigeria (Adekoyeni., Akinoso, & Malomo, 2012; Longtau, 2003). Different ecological zones in Nigeria adopt different paddy pre-treatments method (Sanni, Okeleye, Soyode, & Taiwo, 2005). This among other factors is responsible for numerous variation in milled rice quality produced in Nigeria.

Rice is mostly consumed as milled or white rice produced by dehulling and milling processes which involves the removal of the hull and bran layers of the rough rice kernel (paddy) respectively. However, Anuonye, Daramola, Chinma, and Banso (2016) reported significant variation in proximate composition due to different processing conditions adopted. It was observed that prolonged soaking of rice paddy led to increase in protein content due to the fermentative activities of fermenting microorganism.

Rice parboiling processes involve four major stages, which are soaking, steaming, drying and milling. During soaking, paddy is soaked in cold or warm water for a duration that is majorly dependent on the cultural practices of the area of production (Adekoyeni, 2014). Steeping of rice paddy in some ecology zone is done for five days whereas at some places soaking could just be done for just some hours. Using experimental design tools such as response surface methodology is critical in identifying variations in composition of rice as affected by pre-treatment method. The use of response surface methodology cut across the generation of composite conditions that aids results interpretation. There is a need to establish the variation in chemical properties as affected by variation in rice paddy pre-treatments. Previous researches on rice *(Oryza sativa L.* variety OS-6) have not focused on a combination of soaking duration, initial soaking temperature, parboiling temperature and drying temperature as paddy pre-treatments conditions. Therefore, the present work is to evaluate and optimise chemical properties of parboiled rice in relation to paddy pre-treatments (soaking duration, initial soaking temperature, parboiling temperature and drying temperature).

2. MATERIALS AND METHODS

2.1. Experimental Design and Paddy Rice Processing

Critical control points (initial soaking temperature, soaking duration, parboiling temperature and drying temperature) which have been reported to be the traditional stages of processing were used as pre-treatment conditions. Initial soaking duration was varied between 30 ºC and 100 ºC considering the effect of initial soaking temperature on rice quality as reported by Anuonye et al. (2016). Soaking duration of 1 to 5 days was used as it has been found to be the traditional practice of local rice processors (Adeniran, Atanda, Edema, & Oyewole, 2012). Parboiling temperature (80 ºC to 120 ºC) and drying temperature (30 ºC to 70 ºC) were used on the basis of established literature data (Adekoyeni.., Sogunle, & Fagbemi, 2015). The method of Adekoyeni.. et al. (2015) as shown in Figure 1 was used for paddy rice processing.

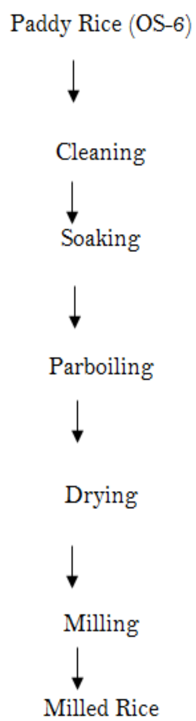

Figure-1. Flowchart for paddy rice processing.
Source: Adekoyeni.. et al. (2015).

2.2. Determination of Proximate Composition

Moisture and crude fibre were determined using (AOAC, 2000). The micro-kjeldahl method (Method No 978.04) (AOAC, 2005) was used in the determination of crude protein. AOAC (2005) method no 930.05 was used to determine the ash content of processed rice while method No 930.09 was adopted for the determination of fat. Carbohydrate content of Ofada rice was obtained by difference. This was done by deducting % protein, %fat, %crude fibre, % ash and % moisture from 100. Protein, fat and carbohydrate which are the three basal nutrients in rice sample were used for energy estimation. This was done by using the FAO (2002) Atwater factor as shown in Equation 1.

$$E\,(\text{kcal}) = (3.82 \times CP) + (8.37 \times CF) + (4.16 \times CHO) \quad (1)$$

Where E = Energy.

CP = Crude protein.

CF = Crude fat.

CHO = Carbohydrate.

2.3. Determination of Acid Value and Free Fatty Acids

The free fatty acid content was determined by using AOAC method 940.28 (AOAC, 2000). The oil sample (0.2 g) was dissolved in 10 mL ethanol and titrated with 0.1M NaOH solution using phenolphthalein indicator until pink colour disappeared. The acid value and the percentage fatty acid were calculated from the expression given in Equation 2 and 3 respectively.

$$\text{Acid value} = \frac{56 \text{ x molarity of NaOH x titre value}}{\text{weight of oil}} \quad (2)$$

$$\%\ \text{Free fatty Acid as Oleic acid} = 0.503 \text{ x Acid Value} \quad (3)$$

2.4. Determination of Amylose and Amylopectin

The amylose content was determined according to the method of Janaun et al. (2016). 0.1 g of grinded rice was added into 100 mL of volumetric flask. 1.0 ml of 95% of Ethanol and 9.0 mL of NaOH were added into the 100 mL volumetric flask. The sample was shaken well and boiled over shaking water bath (BS-31) for 10 minutes. After which the solution was cooled and was made up to 100 mL using distilled water. Next, 5 mL from the 100 mL sample was pipetted out to another 100 mL of volumetric flask. Then 1 mL of 1 M acetic acid and 2 mL of I-KI was added into the solution and its volume was made up to 100 mL. The solution was shaken and allow to stand for 20 minutes before absorbance of the solution was determined at wavelength of 620 nm using UV-Vis Spectrophotometer JASCO V-650. The amylose concentration of the sample was determined from the standard curve.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of Milled Ofada Rice

As presented in Table 1, the maximum and the least percentage of moisture recorded for processed rice were 10.24 and 4.22%. The mean value was 8.89 %. Treatments with 1 day soaking, 100 °C paddy soaking temperature, 80 °C parboiling temperature, 30 °C drying temperature and treatments with 5 days soaking, 100 °C initial soaking temperature and 120 °C parboiling temperature, 30 °C drying temperature had the highest moisture content. The lowest moisture content was obtained from 1 day paddy soaking, 30 °C initial soaking temperature, 100 °C parboiling temperature and 70 °C drying temperature. There were significant differences among most treatments. This could be associated with variation in the drying temperature. Moisture content reported in this work is lower than that obtained by Adeniran et al. (2012) but within the range of that reported by Anuonye et al. (2016) who reported moisture content range of 8.24 to 10.21 g/100g. When sun drying was used by Fagbohun and Oluwaniyi (2015) in a study on milled rice storage, a range of 7.84 to 11.72 % was obtained for milled rice moisture content. Variations in the percentage of moisture content reported by researchers could be due to drying method adopted, prevailing environmental conditions (Ebuchi & Oyewole, 2007) and probably due to the nature of the seed coat and pericarp which could be waxy (Roy, Orikasa, Okadome, Nakamura, & Shiina, 2011).

Oko, Ubi, Efisue, and Dambaba (2012) opined that palatability of rice is greatly affected by the moisture content. Adekoyeni (2014) noted the significance of moisture content in rice as an index of quality and stability in storage. 12 to 14 % moisture content has been suggested as the optimum storage condition for rice. Suitable moisture content is necessary because of the hygroscopic nature of milled rice (Fagbohun & Oluwaniyi, 2015) coupled with the fact that moisture content of milled rice influences the microbial growth and hence shelf life of milled rice.

Ash content of processed rice ranged from 0.24 to 0.71 with an average value of 0.515 %. Ash content reported in this work is lower than that obtained by Adeniran et al. (2012) but within the range of that reported by Adekoyeni (2014) in a study of effect of storage and processing condition on Ofada rice quality.

Ash content obtained in the present study is in congruence with the work of Anuonye et al. (2016), who reported that soaking Ofada rice paddy overnight gave the highest percentage (1.78) of ash while the lowest (1.17 %) was obtained when paddy was soaked for eight days. The significant decrease ($P < 0.05$) in the ash content of milled rice could be attributed to loss of nutrient due to leaching that occurs during prolonged soaking of Ofada rice paddy.

Ofada rice fat content ranged from 0.62 to 1.73 %. Significant differences at $p < 0.05$ exist among some treatments while most treatments had no significant differences. Variation in the percentage of fat in milled rice has been linked to the effect of variation in temperature (Fennema, 1996). The treatments that gave the highest and lowest value of fat in this work agreed with the observation of Fennema (1996). Adekoyeni (2014) also reported the lowest fat content when the drying temperature was the lowest. Fat content in Ofada rice was low because most of the fats are located in the rice bran (Akinoso & Adeyanju, 2010) which is removed in greater percentage during rice milling.

The highest and lowest protein contents of processed rice were 9.57 and 7.41 % respectively with average value of 8.52 %. Significant differences were found among treatments at $p < 0.05$. The highest content of protein was recorded at 5 days soaking, 100 ^{o}C initial soaking temperature, 80 ^{o}C parboiling temperature and 50 ^{o}C drying temperature while the lowest was obtained when paddy rice was soaked for 1 day with initial soaking temperature of 30 ^{o}C parboiling temperature of 120 ^{o}C and dried at 30 ^{o}C. These results are in agreement with the work of Joseph (2015) who obtained protein content range of 7.22 to 11.29 for African rice varieties. Having the highest protein content after 5 days soaking might be due to the effect of fermentation which has been reported to increase the protein content of cereals. This is in agreement with the work of Anuonye et al. (2016) where the highest percentage of protein was obtained from Ofada rice paddy soaked for eight days.

Crude fibre content of processed rice has its maximum and minimum value as 1.71 and 0.60 respectively. Range of crude fibre (0.12 – 0.37 %) obtained by Adekoyeni (2014) was low compared to that obtain in the present study. The work of Ibukun (2008) and Adepoju, Akinleye, and Ajayi (2016) on Ofada rice reported a range of 1.02 -1.76 % and 0.94-1.19 % respectively which are in agreement with this work. A proximate analysis of local rice varieties in Ghana carried out by Wireko-Manu and Amamoo (2017) reported a fibre content of 0.64-1.95 % which is within the range of that obtained for Ofada rice in this study. Higher percentage of crude fibre in local rice compared to imported rice was attributed to the extent of milling (Wireko-Manu & Amamoo, 2017). This is because the greater percentage of crude fibre is located in the rice bran.

Table-1. Result of Chemical Properties of Ofada rice.

Run	Soaking duration	Initial Soaking Temperature	Parboiling Temperature	Drying Temperature	Moisture	Ash	Fat	Protein	Crude fibre	Carbohydrate	Energy	Free fatty acid	Amylose
	(Days)	^{o}C	^{o}C	^{o}C	%	%	%	%	%	%	kcal	%	%
2	1	30	80	50	8.36^{de}	0.55^{efg}	0.64^{a}	8.45^{ef}	0.75^{de}	81.30^{m}	364.73^{fgh}	0.78^{abc}	17.81^{a}
6	1	30	100	70	4.22^{a}	0.63^{ghi}	0.62^{a}	8.91^{j}	1.00^{a}	84.65^{n}	379.82^{k}	2.59^{k}	19.25^{abcd}
15	1	30	120	30	9.73^{ij}	0.57^{efg}	0.77^{abc}	7.41^{a}	0.70^{ij}	80.85^{ki}	359.97^{bcd}	1.39^{e}	18.09^{a}
24	1	30	120	30	9.49^{ghi}	0.58^{efg}	1.03^{def}	8.88^{j}	1.35^{hi}	78.70^{bc}	359.58^{b}	1.37^{e}	17.48^{a}
8	1	65	100	50	8.08^{cd}	0.71^{h}	1.04^{def}	8.61^{fghi}	1.15^{cd}	80.44^{jk}	365.56^{i}	2.05^{ij}	17.41^{a}
11	1	65	120	70	6.65^{b}	0.59^{efg}	0.98^{cde}	8.59^{fghi}	1.26^{b}	81.96^{n}	371.03^{j}	1.81^{gh}	19.11^{abcd}
18	1	100	80	70	7.72^{c}	0.47^{bcd}	1.03^{def}	8.09^{c}	0.78^{c}	81.95^{m}	369.42^{j}	1.48^{ab}	18.43^{abc}
20	1	100	80	30	10.24^{j}	0.38^{b}	1.05^{def}	9.37^{k}	0.65^{j}	78.5^{bc}	361.08^{bcde}	2.13^{j}	17.65^{a}
25	1	100	80	30	9.45^{ghi}	0.40^{b}	1.05^{def}	7.58^{b}	0.59^{ghi}	80.96^{lm}	363.62^{efg}	2.73^{k}	17.76^{a}
13	1	100	120	50	8.72^{e}	0.40^{b}	1.73^{j}	8.66^{ghi}	0.57^{e}	79.95^{hi}	370.01^{j}	0.97^{cd}	17.61^{a}
16	3	30	100	50	9.46^{ghi}	0.41^{b}	1.19^{efgh}	8.49^{fg}	1.71^{ghi}	78.77^{c}	359.77^{bc}	1.32^{e}	22.34^{e}
12	3	30	120	70	8.64^{de}	0.24^{a}	1.11^{defg}	8.24^{cd}	0.85d^{e}	80.96^{hi}	366.79^{i}	1.0oC^{d}	21.31^{de}
7	3	65	100	70	8.24^{cde}	0.60^{fg}	1.35^{hi}	8.76^{ij}	1.2oC^{de}	79.89^{ghi}	366.74^{gh}	1.34^{e}	21.19^{de}
14	3	65	100	40	9.48^{hi}	0.58^{efg}	1.35^{i}	8.56^{fgh}	0.79^{hi}	79.27^{def}	363.48^{efg}	2.00^{hij}	22.55^{de}
5	3	100	100	50	9.85^{ij}	0.57^{efg}	1.31^{ghi}	8.73^{hij}	1.26^{ij}	78.31^{ab}	359.97^{bcd}	3.52^{l}	21.44^{de}
9	5	30	80	30	8.77^{ef}	0.57^{efg}	1.17^{defghi}	8.86^{j}	1.22^{ef}	79.44^{efg}	363.73^{efg}	3.80^{m}	20.83^{cde}
10	5	30	80	30	9.42^{ghi}	0.57^{efg}	1.26^{fghi}	8.19^{cd}	0.99^{ghi}	80.21g^{ij}	359.53^{b}	2.73^{k}	20.83^{cde}
17	5	30	80	70	8.87^{efgh}	0.51^{cde}	1.05^{def}	8.42^{ef}	0.73^{efgh}	80.46^{ejk}	364.97^{fgh}	0.74^{b}	20.95^{cde}
1	5	30	120	50	8.81^{efg}	0.59^{efg}	1.26^{fghi}	7.52^{ab}	1.04^{efg}	80.81^{kl}	364.66^{fgh}	0.70^{a}	17.83^{a}
21	5	65	100	50	9.81^{ij}	0.43^{bc}	1.09^{defg}	8.46^{ef}	0.57^{ij}	79.66^{efgh}	362.31^{cdef}	0.98^{cd}	21.04^{cde}
23	5	100	80	50	9.45^{ghi}	0.54^{de}	0.94^{bc}	9.57^{l}	0.60^{ij}	78.93^{cd}	362.48^{def}	1.86^{ghi}	18.39^{abc}
3	5	100	120	70	9.37^{fghi}	0.64^{gh}	1.15^{defghi}	8.50^{fg}	0.67^{fghi}	79.70^{fgh}	363.13^{efg}	0.95^{bcd}	21.71^{de}
4	5	100	120	30	10.24^{j}	0.40^{b}	1.27^{fghi}	9.42^{kl}	0.63^{j}	78.07^{a}	361.39^{bcd}	1.84^{ghi}	20.65^{bcde}
19	5	100	120	30	10.15^{j}	0.58^{efg}	1.06^{defg}	8.3^{d}	1.01^{j}	79.23^{de}	356.98^{a}	1.64^{fg}	20.53^{bcde}
22	5	100	120	70	9.81^{ij}	0.51^{cde}	0.68^{a}	8.51^{fg}	0.84^{ij}	79.68^{efgh}	358.88^{ab}	1.05^{cd}	21.19^{de}

Note: Means in the same column having same letter are significantly not different ($p > 0.05$).

Amount of carbohydrate present in processed rice ranged from 78.31 to 84.65 % with an average value of 80.12 %. There is significant difference at p <0.05 among treatments in their carbohydrate contents. 1, 3 and 5 days soaking treatments had their highest percentages as 84.65, 80.96 and 80.46 % respectively. Decrease in carbohydrate content as the soaking duration increased was also reported by Anuonye et al. (2016). This was caused by loss of carbohydrate due to its solubility in soak water. Range of carbohydrate reported in this work is in agreement with that obtained by Adekoyeni (2014) who reported a range of 78.58 to 84.35 %. Fagbohun and Oluwaniyi (2015) reported a comparatively lower percentage range (63.72 to 61.28 %) for Ofada rice. This might be due to the higher protein content reported by Fagbohun and Oluwaniyi (2015) during rice storage.

The highest energy value (379.82 kcal/100g) was obtained when paddy rice was soaked for 1 day with initial soaking temperature of 30 °C, parboiled at 100 °C and dried at 70 °C. Whereas the least value (356.98 kcal/100g) was obtained with paddy treatment of 5 day soaking, 100 °C initial soaking temperature, 120 °C parboiling temperature and 30 °C drying temperature. The result of energy value showed significant difference existed among treatments at p <0.05. Result of energy reported in this work is lower than that reported by Adekoyeni (2014) (367.18 - 400.40 kcal/100g) but within the range of that reported by Anuonye et al. (2016) (357.72 - 368.68 kcal/100g) and Anuonye et al. (2016) (366.75 - 371.50 kcal/100g). Decline in energy value of rice with increase in fermentation duration observed in this work was also reported by Anuonye et al. (2016) who reported 368.68 kcal/100g for Ofada rice soaked overnight and 357.72 kcal/100g for paddy rice soaked for eight days. Attributed to the significant decline in energy value due to increase in soaking duration is the leaching of water soluble nutrients into the soak water (Abulude, 2004; Jafar, Basem, Maha, & Khalil, 2008).

3.2. Amylose Content of Ofada rice

Major organoleptic characteristics influenced by amylose content are texture and taste of the cooked rice (Futakuchi & Sié, 2009; Zhang, Zhao, & Xiong, 2010). Amylose content of processed rice in this study varied from 17.41 to 22.34% with an average value of 19.734 %. The highest value was obtained at 3 days soaking, 30 °C initial soaking temperature, 100 °C parboiling temperature and 50 °C drying temperature while the least amylose content was recorded from treatment with 1 day soaking, 65 °C initial soaking temperature, 100 °C parboiling temperature and 50 °C drying temperature.

There was no significant difference among most of the treatments at 5% level of significance. The highest values for 1, 3 and 5 days soaking treatments were 19.11, 22.34 and 21.71 respectively while the lowest percentages were 17.41, 21.19 and 18.39% respectively. In agreement with these values is the work of Danbaba, Anounye, Gana, Abo, and Ukwungwu (2011) who reported a range of 19.77 to 24.13% amylose for Ofada rice (FARO 42). According to the grouping of amylose content by Cruz and Khush (2000) Ofada rice can be referred to as intermediate amylose rice. This was also observed by other researchers (Anuonye et al., 2016; Danbaba et al., 2011).

The highest percentage of amylose reported in this work is more than the highest reported by Adeniran et al. (2012) although the value is still within the range of the amylose reported in this work. Decrease in amylose due to parboiling has been reported by researchers (Adeniran et al., 2012; Otegbayo, Osamuel, & Fashakin, 2001). Decrease in amylose content has been attributed to starch solubilisation and subsequent loss of amylose molecules during soaking and parboiling (Otegbayo et al., 2001). However decrease in amylose is subject to the level and duration hydration. Adekoyeni.. et al. (2015) in a study of the influence of storage, soaking, parboiling temperature and drying temperature of milled Ofada rice reported a significant difference in the level of amylose. On the contrary, Anuonye et al. (2016) observed no significant differences in amylose after soaking rice paddy for eight days in a comparative study between traditional and improved method of paddy rice processing. In the present study, significant difference not existing among treatments is an evidence of the fact that the level and duration of hydration was not enough to cause loss of amylose (Anuonye et al., 2016).

3.3. Free Fatty Acid Content of Ofada Rice

Palmitic, stearic, oleic and linoleic acid are the main free fatty acid found in rice (Zhou, Robards, Helliwell, & Blanchard, 2002). The highest value of free fatty acid in processed rice was (3.80 %) obtained at 5 days soaking, 30 ^{o}C initial soaking temperature, 80 ^{o}C parboiling temperature and 30 ^{o}C drying temperature, while the least value of 0.70 % was obtained from 5 days soaking, 30 ^{o}C initial soaking temperature, 120 ^{o}C parboiling temperature and 50 ^{o}C drying temperature. Significant difference ($p < 0.05$) existed among treatments with respect to their percentage of free fatty acid. 1, 3 and 5 days soaking treatments had their highest values as 2.59, 3.52 and 3.80 % respectively, while the free fatty acid least values were 0.78, 1.00 and 0.70 %respectively.

Increase in free fatty acid due to increase in soaking duration observed in this work was also reported by Adekoyeni (2014). The highest free fatty acid (4.78) reported by Adekoyeni (2014) was obtained when paddy was stored for 1 month, soaked for 5 days, parboiled at 80 ^{o}C and dried at 30 ^{o}C while he had the lowest percentage (1.23) with the following treatment: 1month paddy storage, 5 days soaking, 120 ^{o}C parboiling temperature, 70 ^{o}C drying temperature. Decrease in the free fatty acid at higher processing temperature in this study could be due to the inactivity of the enzyme lipase at high temperature. Lipolytic reactions that leads to the production of free fatty acid is always catalysed by lipases (Fennema, 1996).

Free fatty acid being a product of lipid hydrolysis has been reported to contribute significantly to the organoleptic properties of rice (Doblado-Maldonado, Pike, Sweley, & Rose, 2012; Zhou et al., 2002). Volatile off-flavours were reported to originate from high free fatty acid (Galliard, 1989). As observed by Galliard (1989), the off-flavour is from conjugated diene hydroperoxides which is a product of oxidation of unsaturated free fatty acid.

3.4. Modelling and Optimization Chemical Properties of Ofada Rice

Estimated coefficient of model showing the effect of Ofada rice paddy pre-treatments on chemical properties is presented in Table 2 while analysis of variance for the model is in Table 3. From the model coefficient in Table 2, increase in soaking time led to increase in moisture content, ash, protein and amylose. Whereas increase in initial soaking temperature has a positive effect on the moisture, fat, protein, free fatty acid and amylose contents. Increase in drying temperature led to increase in ash, carbohydrate, energy and amylose content. Raising parboiling temperature has causes reduction in carbohydrate and free fatty acid contents.

Adequate precision value of moisture, fat, protein, carbohydrate, energy, FFA and amylose greater than 4 is an indication of the suitability of the model of the design. The negative value of predicted R-squared Table 3 is an indication that mean value could be used to estimate the effect of paddy pre-treatments on chemical properties. The R^2 and p-value obtained for moisture, carbohydrate, energy, FFA and amylose affirms the fitness of their respective models.

As shown in Table 4 optimisation goal to obtain the most suitable paddy treatment were set to have moisture content, fat and free fatty acid at minimum, while protein, carbohydrate, crude fibre, energy and amylose content were set at maximum. The solutions predicted to be suitable for the optimisation goals is as presented in Table 4. Among ten (10) predicted optimisation solutions, soaking duration of 1 day: 4.8 minutes, initial soaking temperature of 35 ^{o}C, Parboiling temperature of 98.03 ^{o}C and drying temperature of 70 ^{o}C had the highest desirability of 0.68.

Table-2. Estimated Coefficient of the model showing the effect of Ofada rice paddy pre-treatments on proximate, amylose and free fatty acid.

Factor	Moisture content	Ash	Fat	Protein	Crude fibre	Carbohydrate	Energy	Free fatty acid	Amylose
Intercept	9.86	0.54	1.37	8.61	1.08	78.56	361.01	1.53	21.53
A-Soaking time	0.57	0.01	-0.02	0.05	-0.03	-0.59	-2.28	-0.05	0.96
B-Initial Soaking Temperature	0.28	-0.03	0.10	0.25	-0.07	-0.54	-0.28	0.37	0.03
C-Drying Temperature	-0.91	0.02	-0.02	-0.02	-0.02	0.94	3.55	-0.47	0.11
D-Parboiling Temperature	-0.01	-0.00	0.13	-0.18	0.07	-0.02	0.39	-0.22	0.02
A^2	-1.37	0.09	-0.26	-0.03	-0.19	1.75	4.55	0.09	-2.41
B^2	-0.42	-0.04	-0.04	0.06	0.12	0.33	1.22	0.66	0.03
C^2	-0.35	0.00	-0.14	0.00	0.06	0.43	0.47	0.59	1.10
D^2	1.10	-0.08	0.03	-0.13	-0.25	-0.67	-2.89	-1.20	-0.91
AB	-0.07	0.03	-0.19	0.27	-0.02	-0.02	-0.68	0.01	0.06
AC	0.74	-0.02	0.04	-0.10	-0.10	-0.57	-2.33	-0.41	0.00
AD	0.16	-0.01	-0.06	-0.27	-0.01	0.18	-0.85	-0.30	-0.00
BC	0.21	0.06	-0.01	-0.16	0.09	-0.19	-1.46	0.05	0.14
BD	0.10	0.02	0.03	0.05	0.00	-0.21	-0.34	-0.07	0.55
CD	-0.277	-0.02	-0.06	0.10	0.03	0.24	0.77	0.44	0.11

Table-3. ANOVA of Ofada rice chemical properties.

	Moisture	Ash	Fat	Protein	Crude fibre	Carbohydrate	Energy	Free fatty acid	Amylose
R-Squared	0.922	0.545	0.717	0.457	0.500	0.818	0.832	0.802	0.905
Adj R-Squared	0.813	-0.090	0.322	-0.303	-0.198	0.563	0.5956	0.524	0.772
Pred R-Squared	-0.438	-6.187	-1.106	-1.526	-5.425	-0.152	-1.468	-2.005	-0.980
Adeq Precision	12.704	3.418	6.279	4.293	3.002	7.981	7.366	6.402	7.898
P-value	0.0009	0.614	0.1735	0.813	0.724	0.035	0.026	0.049	0.002

Table-4. Predicted optimization solutions for Ofada rice chemical qualities .

Number	Soaking time	Initial Soaking Temperature	Drying Temperature	Parboiling Temperature	Moisture	Ash	Fat	crude fible	Protein	Carbohydrate	Energy	Free fatty acid	Amylose	Desirability
1	1.02	35.00	70.00	98.03	5.03	0.61	0.62	1.14	8.83	83.80	376.10	2.37	19.39	0.68
2	1.06	35.00	70.00	101.47	5.02	0.60	0.65	1.16	8.85	83.75	376.25	2.46	19.43	0.67
3	1.28	35.00	70.00	97.10	5.57	0.59	0.70	1.16	8.79	83.21	374.38	2.25	20.09	0.67
4	1.05	35.00	69.12	95.90	5.31	0.61	0.63	1.12	8.80	83.56	375.17	2.21	19.42	0.67
5	1.18	35.00	69.18	94.61	5.62	0.60	0.67	1.12	8.78	83.24	374.19	2.11	19.77	0.67
6	1.00	35.00	66.93	99.28	5.34	0.62	0.66	1.13	8.81	83.48	375.13	2.27	19.01	0.65
7	1.00	35.00	64.40	90.76	6.07	0.62	0.65	1.02	8.71	82.96	372.59	1.71	18.80	0.61
8	3.83	38.86	70.00	101.67	8.17	0.49	1.14	1.13	8.41	80.68	366.70	1.62	22.55	0.52
9	5.00	85.56	70.00	101.11	8.66	0.66	0.91	0.85	8.71	80.23	364.00	1.71	21.47	0.48
10	5.00	73.63	32.17	100.50	8.94	0.63	0.95	0.99	8.84	79.68	362.65	2.88	20.86	0.42

4. CONCLUSION AND RECOMMENDATIONS

Chemical changes associated with Ofada rice paddy pre-treatments conditions of soaking duration, initial soaking temperature, parboiling temperature and drying temperature were determined. Increase in soaking duration led to increase in FFA and protein, decrease in energy, ash and carbohydrate. The fat content was negatively affected by soaking duration and drying temperature. The R^2 for the model fitted ranged from 0.457 to 0.922. R^2 obtained for moisture, carbohydrate, energy, FFA and amylose affirms the fitness of their respective models.

Soaking duration of 1 day: 4.8 minutes, initial soaking temperature of 35 °C, Parboiling temperature of 98.03 °C and drying temperature of 70 °C with a desirability of 0.68 gave the minimum moisture content, fat and free fatty acid while protein, carbohydrate, crude fibre, energy and amylose content were at the maximum.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Acknowledgement: All authors contributed equally to the conception and design of the study.

REFERENCES

Abulude, F. (2004). Effect of processing on nutritional composition, phytate and functional properties of rice (Oryza sativa L) flour. *Nigerian Food Journal, 22*(1), 97-104.

Adekoyeni, O. O. (2014). *Effect of processing conditions on physical, chemical, cooking and sensory properties of Ofada rice(Oryza sativa L.) grain and flakes.* PhD Thesis, University of Ibadan, Department of Food Tehnology.

Adekoyeni., O., Akinoso, R., & Malomo, O. (2012). Some physical properties and yield of Ofada rice. *J. Basic Appl. Sci. Res, 2*(4), 4098-4108.

Adekoyeni.., O. O., Sogunle, K. A., & Fagbemi, S. A. (2015). Effect of storage and processing parameters on protein and amylose of ofada rice grain. *FUDMA Journal of Agriculture and Food Technology, 1*(1), 21 – 30.

Adeniran, O., Atanda, O., Edema, M., & Oyewole, O. (2012). Effect of lactic acid bacteria and yeast starter cultures on the soaking time and quality of "Ofada" rice. *Food and Nutrition Sciences, 2012*(3), 207-211.

Adepoju, O. T., Akinleye, O., & Ajayi, K. (2016). Comparative sudy of nutrient composition and retention of raw and cooked imported and local Rice (Oryza sativa) varieties. *British Journal of Applied Science & Technology, 16*(2), 1-9.

Adeyemi, I., Fagade, S., & Ayotade, K. (1986). Some physicochemical and cooking qualities of Nigeria rice varieties. *Nigerian Food Journal, 4*(1), 26-33.

Akinoso, R., & Adeyanju, J. A. (2010). Optimization of edible oil extraction from ofada rice bran using response surface methodology. *Food and Bioprocess Technology, 2010*(5), 1372-1378.

Anuonye, J., Daramola, O., Chinma, C., & Banso, O. (2016). Effects of processing methods on physicochemical, functional and sensory properties of Ofada rice. *International Journal of Biotechnology and Food Science, 4*(1), 7-14.

AOAC. (2000). *Official methods of analysis. The association of official analytical Chemists* (17th ed.). USA: Horowitz W Edition Maryland.

AOAC. (2005). *Association of official analytical chemists official methods of analysis of AOAC International.* Gaithersburg, MD. USA.

Cruz, N., & Khush, G. S. (2000). Rice grain quality evaluation procedures. In: RK Singh US Singh and GS Khush (Eds). Aromatic rice (pp. 15-28). New Delhi: Oxford and IBH Publishing Co Pvt. Ltd.

Danbaba, N., Anounye, J. C., Gana, A. S., Abo, M. E., & Ukwungwu, M. N. (2011). Grain quality characteristics of ofada rice (Oryza sativa L.): Cooking and eating quality. *International Food Research Journal, 2011*(18), 629-634.

Doblado-Maldonado, A. F., Pike, O. A., Sweley, J. C., & Rose, D. J. (2012). Key issues and challenges in whole wheat flour milling and storage. *Journal of Cereal Science, 56*(2), 119-126. Available at: https://doi.org/10.1016/j.jcs.2012.02.015.

Ebuchi, A. E., & Oyewole, C. O. (2007). Effect of cooking and soaking on physical characteristics, nutrient composition and sensory evaluation of indigenous and foreign rice varieties in Nigeria. *African Journal of Biotechnology, 6*(8), 1016- 1020.

Fagbohun, E. D., & Oluwaniyi, T. T. (2015). Mycoflora, proximate composition and nutritional changes during the storage of Oryza sativa. *Food Science and Quality Management, 2015*(40), 108-116.

FAO. (2002). Food energy- methods of analysis and conversion factors (pp. 3-6). Report of a Technical Workshop. Rome.

Fennema, O. R. (1996). Food Chemistry (3rd ed., pp. 191-201). New York: Mercel Dekker, Inc.

Futakuchi, K., & Sié, M. (2009). Better exploitation of African rice (Oryza glaberrima Steud.) in varietal development for resource-poor farmers in West and Central Africa. *Agricultural Journal, 4*(2), 96-102.

Galliard, T. (1989). *Rancidity in cereal products, in rancidity in foods, edited by J.C. Allen and R.J. Hamilton*. London: Elsevier.

Ibukun, E. (2008). Effect of prolonged parboiling duration on proximate composition of rice. *Scientific Research and Essay, 3*(7), 323-325.

Jafar, M., Basem, F. D., Maha, M., & Khalil, I. E. (2008). Variation in physio-chemical characteristics, mineral concentrations and cookability of rice marketed in Jordan. *Pakistan Journal of Nutrition, 7*(1), 141-145. Available at: https://doi.org/10.3923/pjn.2008.141.145.

Janaun, J., Kong, V. V., Toyu, C. G., Kamin, N. H., Wolyna, P., & Lee, J. S. (2016). *Effect of moisture content and drying method on the amylose content of rice*. Paper presented at the International Conference on Chemical Engineering and Bioprocess Engineering: IOP Publishing. IOP Conference Series: Earth and Environmental Science.

Joseph, K. G. (2015). *Structural and functional characteristics of African rice (oryza glaberrima) flour and starch*. A Thesis Presented to the University of Guelph in Partial fulfillment of Requirements for the Degree of Doctor of Philosophy in Food Science.

Longtau, S. R. (2003). *Nigeria case study report on rice production. Multi-agency partnerships for Technical change in West African agriculture (MAPS)*. Jos, Nigeria: Eco-Systems Development Organization (EDO) for Overseas Development Institute (ODI).

National Cereal Research Institute (NCRI) & Africa Rice Centre (WARDA). (2007). *Definition of Ofada rice qualities through varietal Identification and testing Pro Publication Monograph Series #26*. Abuja, Nigeria.

Oko, A., Ubi, B., Efisue, A., & Dambaba, N. (2012). Comparative analysis of the chemical nutrient composition of selected local and newly introduced rice varieties grown in Ebonyi State of Nigeria. *International Journal of Agriculture and Forestry, 2*(2), 16-23. Available at: https://doi.org/10.5923/j.ijaf.20120202.04.

Otegbayo, B., Osamuel, F., & Fashakin, J. (2001). Effect of parboiling on physico-chemical qualities of two local rice varieties in Nigeria. *Journal of Food Technology in Africa, 6*(4), 130-132.

Roy, P., Orikasa, T., Okadome, H., Nakamura, N., & Shiina, T. (2011). Processing conditions, rice properties, health and environment. *International Journal of Environmental Research and Public Health, 8*(6), 1957-1976. Available at: https://doi.org/10.3390/ijerph8061957.

Sanni, S., Okeleye, K., Soyode, A., & Taiwo, O. (2005). Physico-chemical properties of early and medium maturing upland Nigerian rice varieties. *Nigerian Food Journal, 23*(1), 148-155.

Wireko-Manu, F. D., & Amamoo, C. (2017). Comparative studies on proximate and some mineral composition of selected local rice varieties and imported rice brands in Ghana. *Agriculture and Food Sciences Research, 4*(1), 1-7. Available at: https://doi.org/10.20448/journal.512.2017.41.1.7.

Zhang, Z., Zhao, S., & Xiong, S. (2010). Morphology and physicochemical properties of mechanically activated rice starch. *Carbohydrate Polymers, 79*(2), 341-348. Available at: https://doi.org/10.1016/j.carbpol.2009.08.016.

Zhou, Z., Robards, K., Helliwell, S., & Blanchard, C. (2002). Ageing of stored rice: Changes in chemical and physical attributes. *Journal of Cereal Science, 35*(1), 65-78. Available at: https://doi.org/10.1006/jcrs.2001.0418.