Nutritional Assessment of RicePaddy Soaked in Cold and Warm Water: Examining Processing Variations and Fatty Acid Profiles

Abstract

The cooking process is pivotal in rice preparation, and crucial for eliciting its distinctive flavor. This study evaluated the fatty acid compositions of rice paddy soakedin warm and cold water during rice processing. Applying Gas Chromatography equipped with a flame ionization detector (GC-FID) analysis, the study identified fatty acids including myristic, myristoleic, oleic, linoleic, and vaccenic fatty acids as the predominant components in these samples. Remarkably, the levels of these fatty acids were significantly higher in the ricepaddy soaked in warm waterthan theircounterparts soaked in cold water. However, myristoleic and linoleic acid concentrations were consistently low across all rice. Notably, among warm water-soakedrice paddy, 'EBSA3' displayed the highest concentration of oleic acid. In the principal component analysis (PCA) biplot forcoldwater-soakedriceaccounted for an overall variance of 82.7%, whilewarm water-soakedrice, rose to 89.2%. Additionally, oleic acid exhibited a substantial positive correlation with vaccenic acid in both raw (r = 0.95) and parboiled (r = 0.96) rice samples, indicating a high degree of relatedness. This implies that changes in one trait may indeed influence others in a similar direction. The study reveals that the fatty acid composition of warm water-soaked rice paddy was higher than that of cold water-soaked rice samples.

Keywords:*Oryza sativa*,Abakalikirice landraces, Fatty acids,Nutrient profiling, paddy

Comment [wa1]: Rice naturally contains dietary fatty acids that vary among different landraces however, it can be affected by the method of paddy processing

Comment [wa2]: This study examined the effect of cold water-soaked and warm water-soaked paddy processing methods on the fatty acid content of local rice landraces in AbakalikiNigeria.

Comment [wa3]: Using the

Comment [wa4]: rice paddy

Comment [wa5]: the study revealed that myristic, oleic, linoleic, and vaccenic fatty acids were predominant in the rice landraces

Comment [wa6]: The rice paddy landraces processed in warm water contained higher ($p < 0.05$) fatty acids compared with the cold water-treated samples.

Comment [wa7]: oleic acid (… µg/g).

Comment [wa8]: delete

Introduction

Rice (*Oryza sativa*), revered as one of the world's most vital staple foods, serves as a fundamental source of carbohydrates and as such sustenance for over half of the global population (Byrd-Bredbenner *et al.*,2009). Beyond its role in providing energy, rice boasts a rich nutritional profile, abundant in fiber, vitamins, minerals, and low cholesterol content, making it an indispensable component of a balanced diet (Juliano and Villarreal, 1993; Mohidem*et al.*, 2022). Nigeria, a prominent player in the global rice landscape, emerged prominently in 2009, ranking 12th in rice consumption, 17th in production, and leading the ranks in both Africa and West Africa (FAOSTAT, 2020). With an estimated consumption of 6.7 million tonnes, Nigeria's trajectory in rice consumption displays a consistent upward trend, poised to persist into the foreseeable future (Juwonlo, 2023).

Although Rice processing does not have a uniform method of processing after harvesting but most adopted methods of include Cleaning, soaking in warm water, and steaming, drying, and milling. However, of recently, intercepted another method in which the soaking was in cold water for a quite longer time that the usual 12 hours of soaking in warm water. The cold soaking after milling had a different aroma unlike the warm water-soaked rice, hence our motivation to evaluate the fatty acid profiles of warm and cold water-soaked white rice which is largely unexplored within the diverse of rice cultivars of Abakaliki, Nigeria.Essential fatty acids (EFAs), particularly polyunsaturated fatty acids (PUFAs), represent pivotal components of rice, essential for optimal health yet unattainable through endogenous synthesis and thus necessitating dietary intake (Gines and Abugri, 2016). As dietary patterns evolve, characterized by a growing apprehension towards conditions such as atherosclerosis, obesity, and diabetes, the significance of fatty acid composition in food assumes heightened importance (Clemente-Suárez *et al.*, 2023). However, while numerous studies have sought to quantify fatty acids across various rice

Comment [wa9]: is revered

Comment [wa10]: Beyond providing energy, rice is rich in fiber, vitamins, minerals, and has low cholesterol, making it essential in a balanced diet

Comment [wa11]: What of the current ranking?. 2009 is far behind for a contemporary work. Also, avoid using long sentences you can recast this.

Comment [wa12]: delete

Comment [wa13]: cleaning

Comment [wa14]: However, a cold-water treatment with a longer soaking time than the usual 12 hours in warm water has found application in rice paddy processing.

varieties, research specific to cold and warm water-soaked paddy rice variants in the Abakalikiricelandraces remains sparse (Oko and Ugwu, 2011). This study seeks to bridge this gap by meticulously examining the fatty acid profiles of cold and warm water-soaked paddy rice varieties cultivated in Abakaliki, Nigeria.This will shedlight on an aspect crucial for both nutritional understanding and consumer preferences.

2.0 Materials and Methods

2.1 Sample collection

A total of fifteen samples of Abakaliki rice landraces (Table 1) were meticulously collected from diverse farm sites scattered across Ebonyi State, Nigeria. These samples were directly procured from local farmers, ensuring authenticity, and representing the regional agricultural landscape comprehensively.

.

Table 1. *Oryza sativa* L. accessions used in the analysis

S/N	CODE	Sources	STATUS	Picture
1	‘EBSA1’	Izza	Landrace	
2	‘EBSA2’	Ikwo	Landrace	
3	‘EBSA3’	Ezzamgbo	Landrace	
4	‘EBSA4’	Ikwo	Landrace	
5	‘EBSA5’	Abaomege	Landrace	
6	‘EBSA6’	Izzi	Landrace	
7	‘EBSA7’	Ikwo	Landrace	
8	‘EBSA8’	Ikwo	Landrace	

Comment [wa15]: Nowadays, Nigeria has a large variety of rice landraces, and it is important to determine their nutritional composition for consumer use and functional food processing (Li et al. 2016). Essential fatty acids (EFAs), particularly polyunsaturated fatty acids (PUFAs), are key components of rice and play a crucial role in promoting optimal health (Gines and Abugri, 2016). Given the increasing concern about conditions such as atherosclerosis, obesity, and diabetes, the importance of dietary fatty acids cannot be overstated (Clemente-Suárez et al., 2023). After harvesting, the most commonly used methods for processing rice paddies include cleaning, soaking in warm water, steaming, drying, and milling. Recently, cold-water treatment with a longer soaking time than the usual 12 hours in warm water has been incorporated into rice paddy processing. Although, variations in the fatty acid content of Abakaliki, Nigeria's rice landrace varieties. Furthermore, the impact of rice paddy processing on the fatty acid content of rice landrace varieties has been reported ( ). However, there is limited information on quantifying the fatty acids content of rice varieties specific to cold and warm water-soaked paddy rice variants in the Abakaliki rice landraces (Oko and Ugwu, 2011). This study determined the fatty acid profiles of cold and warm water-soaked paddy rice varieties cultivated in Abakaliki, Nigeria. This research will provide valuable insights that assist in the nutritional and consumer preferences for the different rice varieties

Comment [wa16]: Delete this, not necessary

Comment [wa17]: The samples were transported to the laboratory of the National Root Crops Research Institute (NRCRI) central molecular and biology laboratory, Umudike, Abia State. For analysis.

9	'EBSA9'	Onueke	Landrace	
10	'EBSA10'	Abakaliki	Landrace	
11	'EBSA11'	Ikwo	Landrace	
12	'EBSA12'	Ikwo	Landrace	
13	'EBSA13'	Ikwo	Landrace	
14	'EBSA14'	Ezza	Landrace	
15	'EBSA15'	Ikwo	Landrace	

Sample preparation

The experiment was carried out in the research and teaching farm of the Department of Crop Production and Landscape Management, Ebonyi State University, Abakaliki, Nigeria, during the dry season of January 2023. A total of 10 kilograms each of 15 distinct rice landrace cultivars were procured directly from local farmers in Ebonyi State, Nigeria. Each cultivar was meticulously divided into two equal portions of 5 kilograms each. The first portion underwent conventional parboiling processes, including soaking in warm water for 12 hours, draining, steaming at 70 degrees Celsius, and sun drying until the moisture content of 15% was achieved. Subsequently, the full dried grains were carefully sealed in waterproof bags and stored at 70% relative humidity. Later, these grains were milled using a specialized testing rice miller. The second portion of each cultivar was cleaned, soaked in cold water for 5 days, drained, steamed at 70 degrees Celsius, and sun drying until the moisture content of 15% was achieved and milled using the same milling machine. Both portions were then ground into fine powder using a blender and sieved separately through a 100-mesh sieve to facilitate the laboratory analysis of fatty acid content.

Comment [wa18]: Delete uncessary

Comment [wa19]: 70 0C

Comment [wa20]: sun-dried

Comment [wa21]: The dried rice grains were sealed in low-density polythene bags and stored at 70% relative humidity.

Comment [wa22]: rice miller (model name)

Comment [wa23]: 70 0 C, and sun-dried

Comment [wa24]: delete, this explanation is not necessary

Extraction and determination of fatty acid profile

The fatty acids in the cold water-soaked and warm water-soaked paddy rice samples were determined using gas chromatography equipped with a flame ionization detector (GC-FID) as described by Hu *et al.*(2023b). Exactly 2.0g of the rice flour was extracted using 5.0 mL toluene and 6.0 mL 10% acetyl chloride (in methanol solution) in a sealed glass tube for two hours at a temperature of 80 ± 0.5 ◦C. The mixture was shaken intermittently every 30 minutes for a complete two hours. The mixture was then cooled to room temperature and transferred together with 3mL of Na_2CO_3 solution, (0.5 mol/L) in a 50ml centrifuge tube. The whole mixture was centrifuged at 2795× g for exactly five minutes before collecting the supernatant and filteringit using 0.45 µm filter film. Exactly 1.0 µL of the filtrate was injected into the GCFID equipped with an HP-88 column (100 m × 0.25 mm × 0.2 µm) and Nitrogen gas at a flow rate of 1.2 mL/min. The injection port temperature was maintained at 260 ◦C with a split ratio of 30:1. The column temperature was adjusted to increase from 120 ◦C to 170 ◦C at a rate of 30 ◦C/min for two minutes, followed by an increase to 200 ◦C at 6 ◦C/min for another 2 minutes. Subsequently, the temperature was raised to 220 ◦C at 20 ◦C/min and further to 230 ◦C at 2 ◦C/min, where it was held for five minutes. Then, the temperature was increased to 232 ◦C at 1 ◦C/min and maintained for 2 minutes before reaching 240 ◦C at 3 ◦C/min and held for five minutes.All experiments were conducted using completely randomized design in triplicate to increase precision of the experiment and ensure the reliability of the results.The laboratory analysis was carried out at the National Root Crops Research Institute (NRCRI) central molecular and biology laboratory, Umudike, Abia State.

Comment [wa25]: delete

Comment [wa26]: at 80 ± 0.5 ◦C.for 3 h.

Comment [wa27]: The mixture was shaken intermittently at 30min intervals for 2 h.

Comment [wa28]: delete

Comment [wa29]: was further

Comment [wa30]: delete this statement here

Data collection

Data were collected from the cold water-soaked and warm water-soaked paddy rice samplesalike on oleic, linoleic, myristic, myristoleic, and vaccenic acids.

Comment [wa31]: not clear

Statistical analysis

Statistical analyses including the descriptive bar chart, principal component, cluster, and correlation were conducted using R (version 4.0.2), with statistical significance set at a p-value of less than 0.05.

Results and Discussion

The findings from our study revealed that all samples analyzed contained the fatty acids examined, namelyMyristics, myristoleic, oleic, vaccenic, and linoleic acids. This aligns with the resultsby Zhou *et al.* (2003) and Hu *et al.* (2023b), who also identified these fatty acids in rice cultivars (Figures 1 and 2). Notably, 'EBSA3'whetherwarm or cold water soakedexhibited significantly higher levels of oleic acid compared to other cultivars, while vaccenic acid predominated in 'EBSA15', 'EBSA11', 'EBSA10', 'EBSA9', and 'EBSA3'. Moreover, all cultivars displayed relatively low levels of myristoleic and linoleic acids in the two paddy treatment rice portions. Particularly, 'EBSA3' among warm water-soaked rice cultivars exhibited the highest concentration of oleic acid when the two rice portions (warmand cold-soaked) were compared.

Comment [wa32]: the **rice paddy contained**

Comment [wa33]: of

Comment [wa34]: This is in line with the findings of Zhou et al. (2003) and Hu et al. (2023b), who also detected these fatty acids in rice varieties (Refer to Figures 1 and 2). Notably, 'EBSA3' had significantly higher levels of oleic acid(µg/g), whether soaked in warm or cold water, thanthe other varieties. Vaccenic acid (µg/g) was predominant in 'EBSA15'( ), 'EBSA11 ( )', 'EBSA10' (), 'EBSA9' ( ), and 'EBSA3 ( )'. NB. **Provide the concentration in the brackets.**

Comment [wa35]: the sample of rice paddy from the treatment methods.

Comment [wa36]: Comparatively, the highest oleic acid (µg/g) concentration was observed in 'EBSA3' rice paddy warm water-soaked than cold-soaked samples.

Comment [wa37]: Delete the extra title

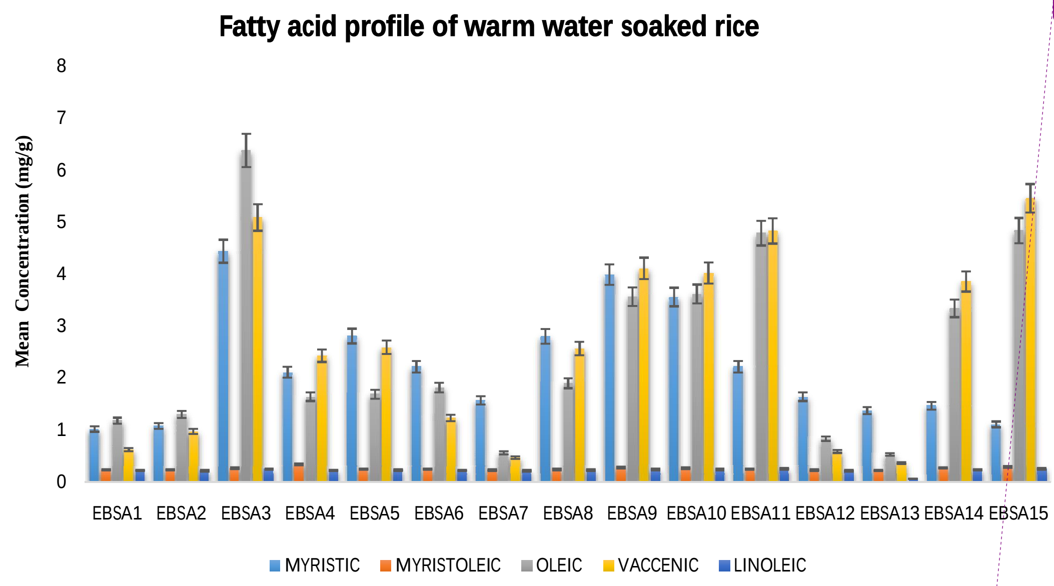


Figure 1: Fatty acidcomposition of the Abakalikiwarm water-soaked ricesamples.

Comment [wa38]: Delete the extra title

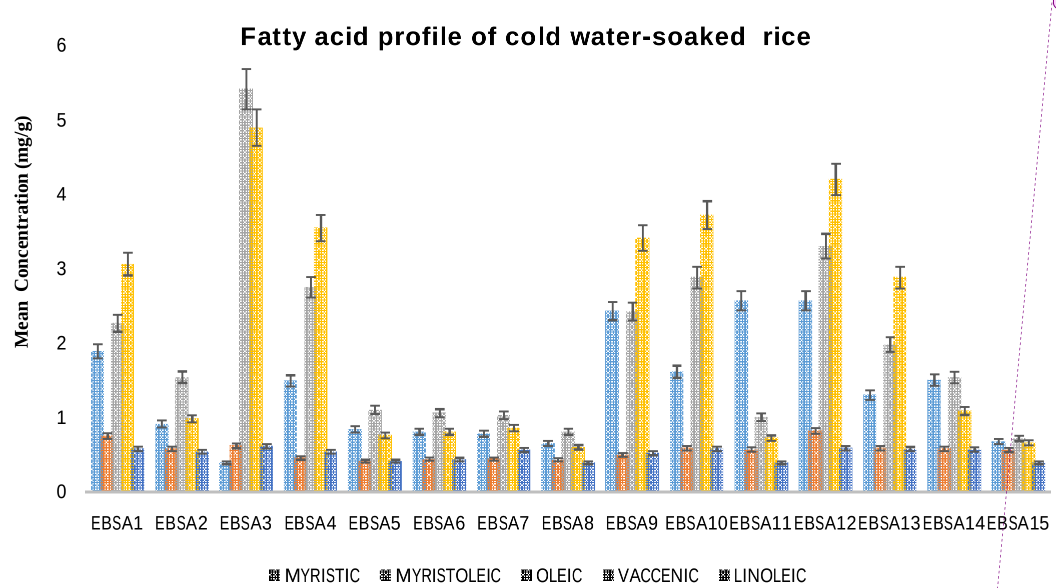


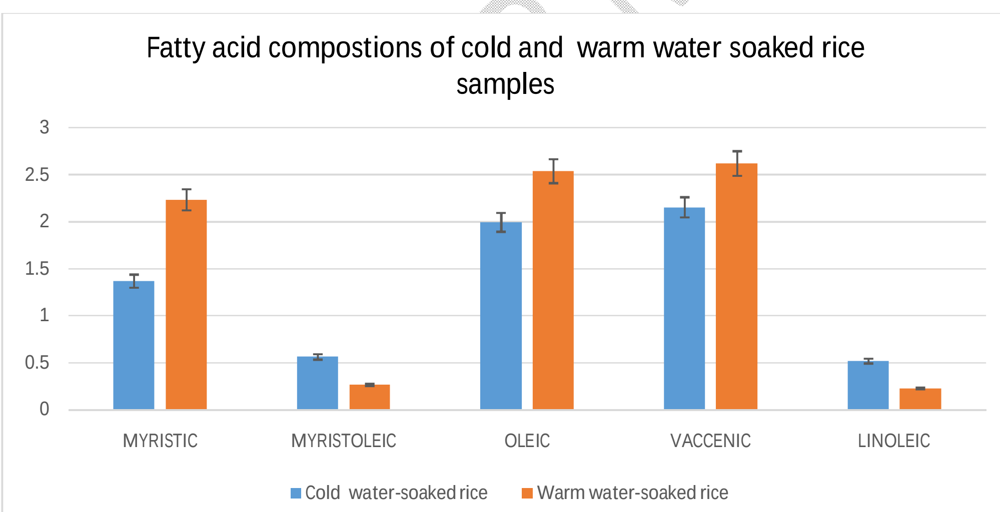
Figure 2: Fatty acid composition of the Abakaliki cold water-soaked rice samples

Interestingly, the overall concentration of all fatty acids was found to be higher in warm water-soaked rice compared to cold water-soaked rice samples in our investigation(Figure 3). This phenomenon could be attributed to the leaching and rupture of oil globules induced by elevated temperature during the 12hrs soaked in warm water process, as suggested by Chukwu and Oseh (2009). Similarly, Hu *et al.* (2023b) and Zhou*et al.* (2024) proposed that cooking enhances the activities of lipase and lipoxygenase, thus facilitating lipid oxidation. Furthermore, several studies have indicated that parboiling rice may enhance grain quality and nutritional content, albeit with the caveat that this process should be conducted promptly (Kimura *et al.*, 1993; Parnsakhorn and Noomhorm, 2008; Danbaba*et al.*, 2014).

Comment [wa39]: Overall, higher concentrations of the fatty acids were found in warm water-soaked rice paddycompared to cold water-soaked samples.

Comment [wa40]: SI unit of time in the second addendum is h and not hrs please.

Comment [wa41]: Delete unnecessaey



Comment [wa42]: delete this extra title, this is not required

Figure 3: Fatty acid compositions of cold and warmwater-soaked Abakaliki ricepaddy

It's noteworthy, as highlighted by Wardlaw and Kessel (2003) and Siri-Tarino*et al.* (2010), that excessive consumption of saturated fats is a key dietary factor contributing to elevated cholesterol levels and potential weight gain. Kromhout *et al.* (1995) and Saraswathi *et al.* (2022) also observed that ingestion of myristic fatty acid, a common saturated fatty acid correlates with increased blood cholesterol levels, potentially exacerbating coronary heart disease risk. However, in comparison to myristic fatty acid, which represents the sole saturated fatty acid in our samples, the dietary fatty acid compositions of our study samples contain a higher proportion of unsaturated fatty acids. This suggests a potentially favorable nutritional profile in terms of lipid intake.

Verma and Srivastav (2017) reported oleic and linoleic acids as major and of course, unsaturated fatty acids which is tipped as being desirable from nutritional and health points of view as their consumption will not lead to heart-related issues (Law, 2000).Whereas myristic on the other hand was reported as minor and saturated fatty acids which can pose health risk such as atherosclerosis, a disease condition associated with heart attack (Oluremi *et al.*, 2013). By and large, the fatty acid profile of rice whether cold water-soaked or warm water-soakedrice, the aromatic and non-aromatic rice accessions have shown that it can be good for consumption if it is well refined (Verma and Srivastav, 2017).

The comprehensive analysis of fatty acid compositions in both cold water-soaked and warm water-soaked rice landraces revealed significant positive correlations across all fatty acids, as determined by Pearson's correlation analysis. Notably, oleic acid exhibited a substantial positive correlation with vaccenic acid in both cold water-soaked (r = 0.95) and warm water-soaked (r = 0.96) rice samples. Additionally, strong positive correlations were observed between oleic and linoleic acid (r = 0.90), as well as between myristic and mystrileic acid (r = 0.81), for cold water-soaked and warm water-soaked rice samples, as illustrated in Figures 4 and 5. These robust and significant correlations among traits suggest a high degree of relatedness, indicating that changes

Comment [wa43]: Based on the findings of Wardlaw and Kessel (2003) and Siri-Tarino et al. (2010), it is evident that excessive consumption of saturated fats significantly contributes to elevated cholesterol levels and weight gain.

Comment [wa44]: Similarly, Kromhout et al. (1995) and Saraswathi et al. (2022) also observed that ingestion of myristic fatty acid, a common saturated fatty acid, correlates with increased blood cholesterol levels, potentially exacerbating the risk of coronary heart disease

Comment [wa45]: Compared to the myristic fatty acid, the only saturated fatty acid in our samples, the dietary fatty acid compositions contain a higher proportion of unsaturated fatty acids. This indicates a potentially beneficial nutritional profile in terms of lipid intake.

Comment [wa46]: No paragraph should be provided here

Comment [wa47]: Myristic on the other hand was reported as minor and saturated fatty acids that can pose risksof atherosclerosis

Comment [wa48]: By and large, the fatty acid profile of rice paddy, whether cold water-soaked or warm water-soaked, indicates that the aromatic and non-aromatic fatty acid contents of the rice accessions can be suitable for consumption if well refined (Verma and Srivastav, 2017)

Comment [wa49]: delete

Comment [wa50]: paddies

in one trait may influence others in the same direction. However, Zaplin*et al*. (2013) reported a strong negative linear relationship between the oleic acid and linoleic acid contents for tested rice grains. The positive significant correlation observed in the present study showed thatone of the traits could be enough selection criteria. Although the traits identifiedas being predominant in the present study were small in number, however, a major advantage of correlation among traits is its ability to identify excessive traits, select fewer traits, and reduce costs in traits analysis, recording and management without undermining experiment precision (Ene *et al.*,2024).

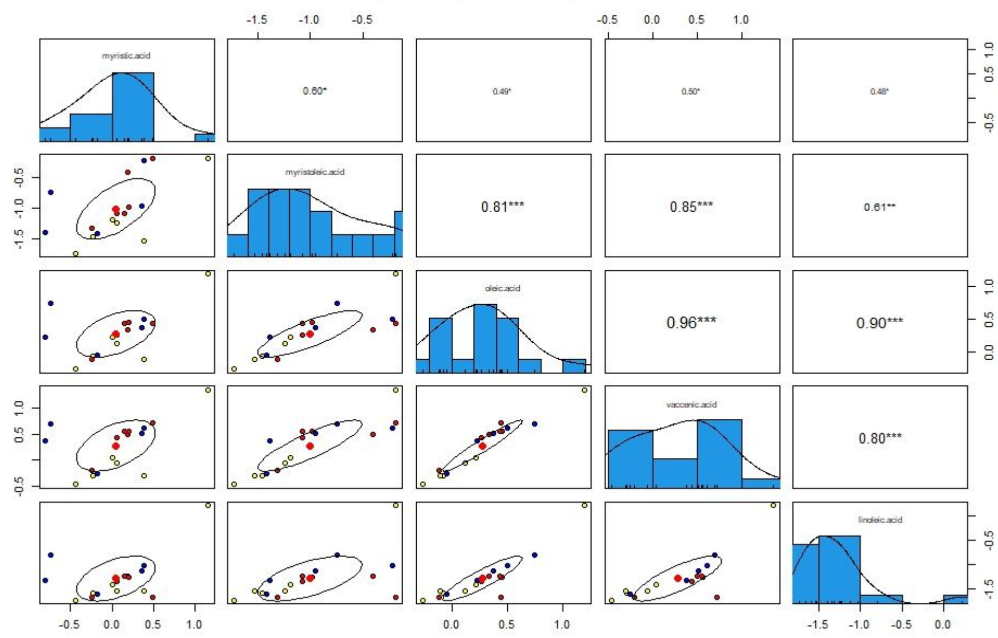


Figure 4: Pearson correlation plot for warm water-soaked rice samples

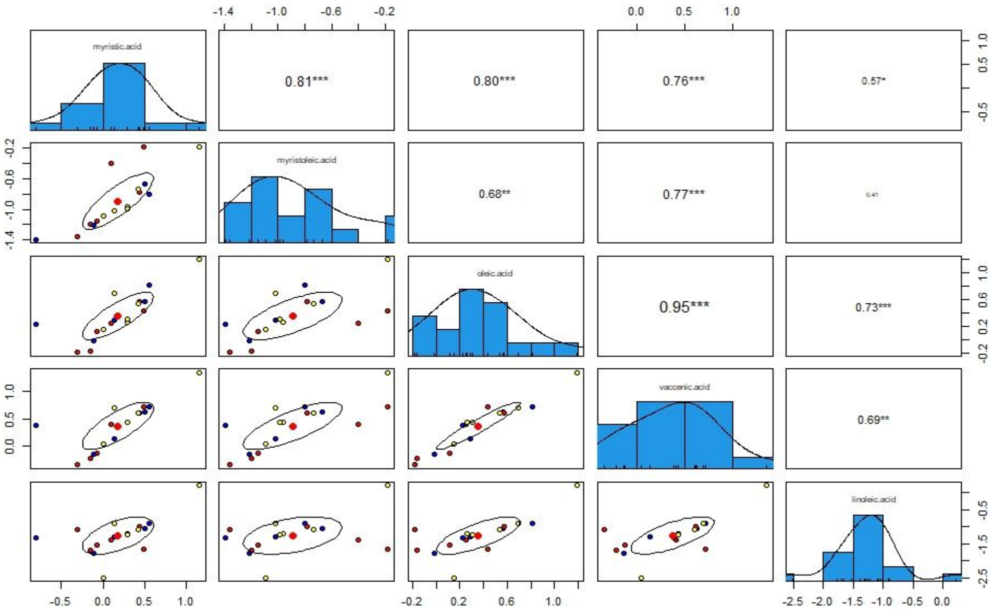


Figure 5: Pearson correlation plot for cold water-soaked ricesamples

Comment [wa51]: paddy

In the biplot of the principal component analysis (PCA) for cold water-soakedrice, an overall variance of82.7% was revealed for dimensions 1 and 2, while for warm water-soaked rice, the overall variance was 89.2%.PC1 accounted for the highest variation at 61% and 65.6% respectively for cold water-soakedand warm water-soaked, while PC2 explained 21.7% and 23.6% for cold and warm water-soaked rice, respectively (Figures 6 and 7).

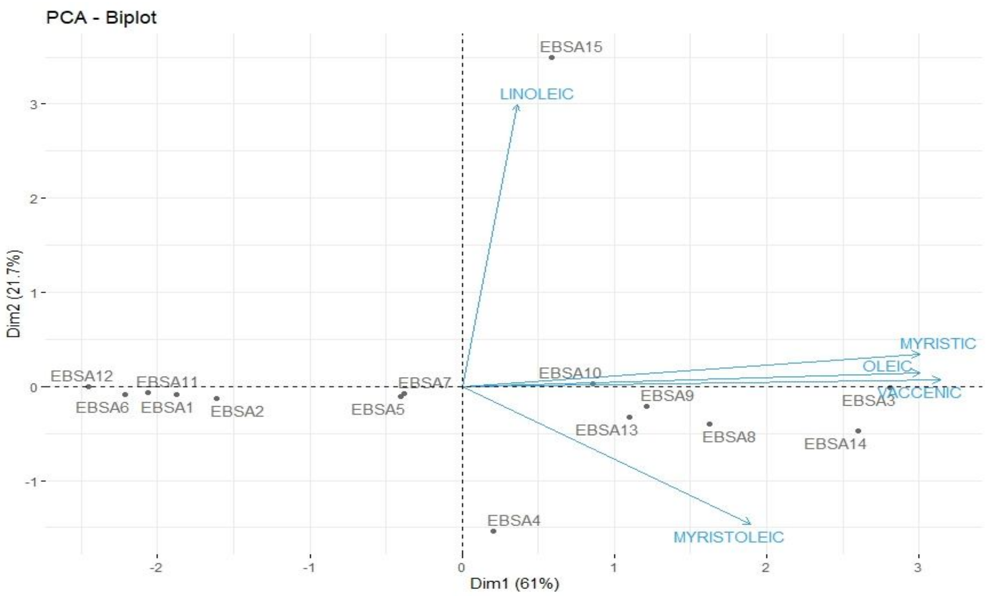


Figure 6: Principal component analysis for fatty acid composition in cold water-soakedrice samples

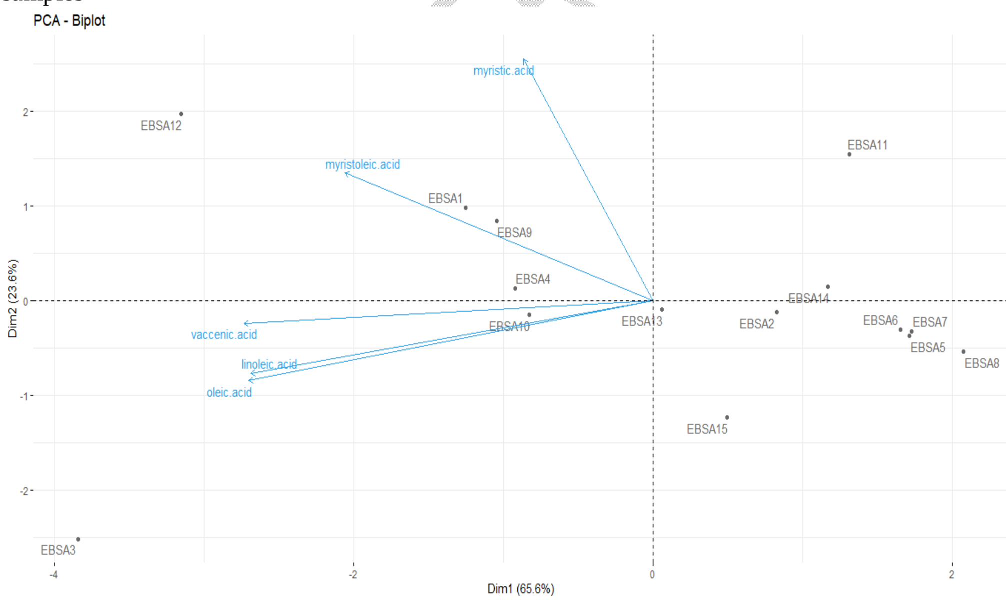


Figure 7: Principal component analysis for fatty acid composition in warm water-soaked rice samples

Based on the factor loadings in cold water-soakedrice, all the fatty acids studied contributed to the variation observed in PC1 indicating a positive correlation among them which is higher among some, with myristoleicacid contributing the most to the variation observed in PC1.Notably, the PCA biplot clearly demonstrated that accessions loading in PC1, particularly 'EBSA3', displayed higher relationship with myristic, oleic and vaccenic acids, while 'EBSA15' showed higher association with linoleic acid content compared to other cultivars loadings in both PC1 and PC2 for the cold water-soakedrice. For the warm water-soaked rice, myristoleic acid was positive with higher factor loading comparable also contributing to the most variation explained but this time in PC2, and mostly associated with 'EBSA12'. Additionally, the plot depicting different dimensions for cold water-soakedriceillustrated that dimensions 4 and 3 exhibited the highest concentrations of myristic and myristoleic acids, respectively while Dim 2,3and 5 had higher concentrations of myristic, myristoleic and oleic acids, respectively were illustrated for warm water-soaked rice (Figures8 and 9). While the present study is limited in terms of the rice samples used andthe number of fatty acids examined; our findings are consistent with those of Hu *et al.* (2023a and 2023b), suggesting an increase in fatty acid content due to an increase in temperature.This is based on the higher cumulative variation recorded in warm water-soaked rice over cold water-soakedrice samples.

Comment [wa52]: In this study, the fatty acids of cold water-soaked rice paddy showed a positive correlation with myristoleic acid contributing the most to the variation observed in PC1 based on the factor loadings.

Comment [wa53]: delete

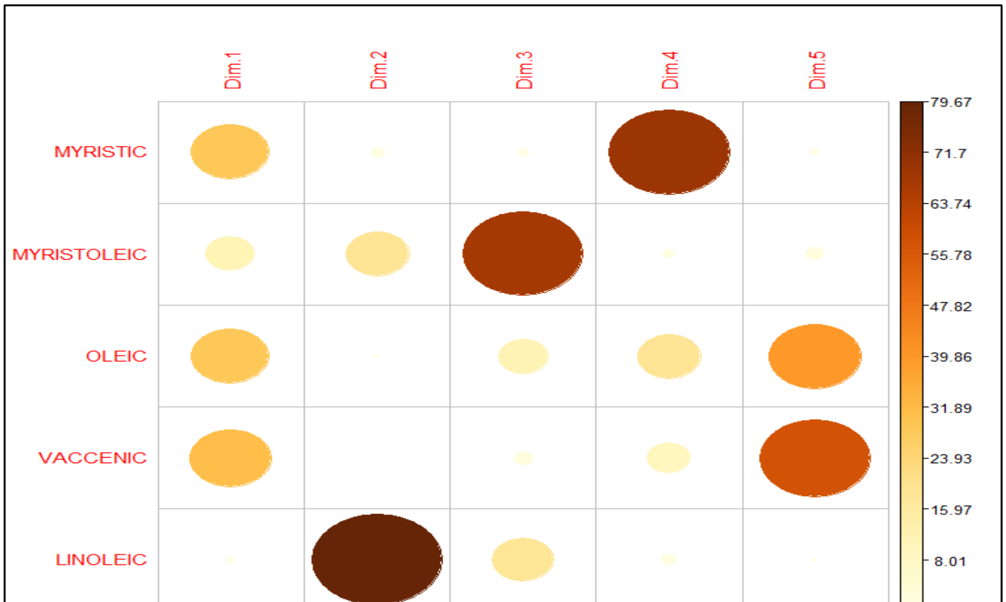


Figure 8: Dimension plots analysis for fatty acid composition in cold water-soaked ricesamples

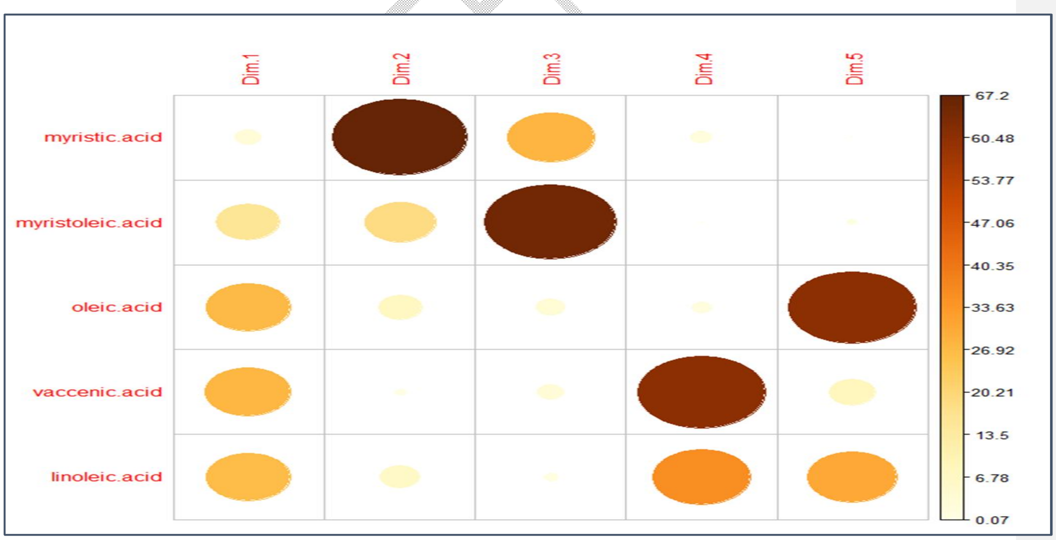


Figure 9: Dimension plots analysis for fatty acid composition in warm water-soaked rice samples

The results of the hierarchical clustering analysis using the pvclust cluster method with AU/BPs P-values in percentages and employing bootstrapping of 10,000 iterations are presented in Figures 10 and 11 for warm water-soaked rice and cold water-soaked rice, respectively. The cluster dendrogram for both cold water-soaked and warm water-soaked rice categorizes the genotypes into two distinct groups, labeled as A and B, based on the similarity of their fatty acid composition. Specifically, Cluster A comprises five cultivars for cold water-soaked rice and six cultivars for warm water-soaked rice, while Cluster B has 10 cultivars for cold water-soakedrice and 9 cultivars for warm water-soaked rice. This analysis yields two types of p-values: AU (Approximately Unbiased) p-value and BP (Bootstrap Probability) value. The AU p-value, obtained through multiscale bootstrap resampling, is considered a more accurate approximation of the unbiased p-value compared to the BP value, which is derived from normal bootstrap resampling. As indicated by Suzuki and Shimodaira (2006) and de Croosand Pálsson (2012), AU p-values exceeding 95% indicate statistically significant clusters.

Comment [wa54]: The results of the hierarchical clustering analysis are displayed in Figures 10 and 11 for warm water-soaked rice and cold water-soaked rice, respectively. The analysis utilized the pvclust cluster method with AU/BPs P-values in percentages and employed bootstrapping of 10,000 iterations.

Comment [wa55]: Observed

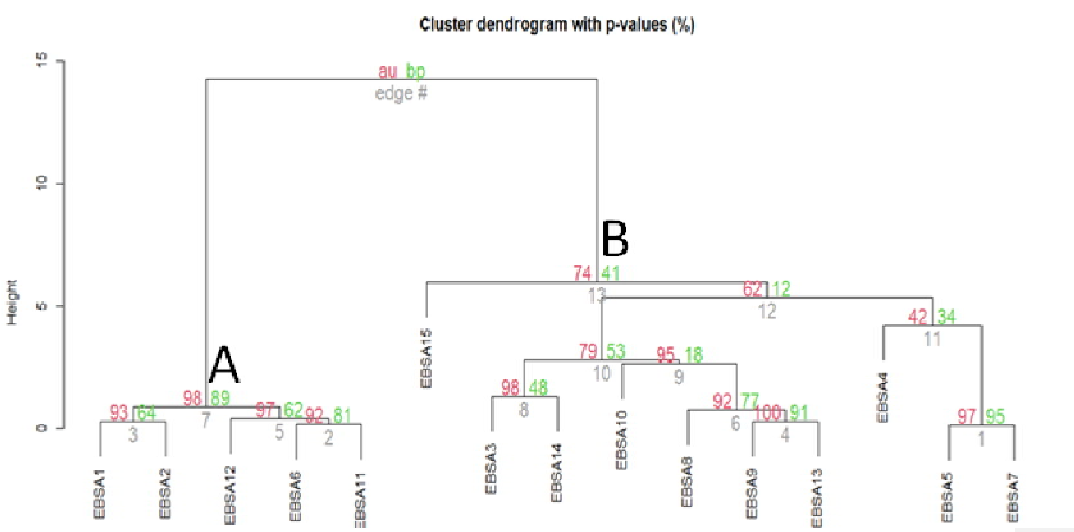


Figure 10: Cluster dendrogram with au/bp values (%) based on fatty acid compositionsin warm water-soaked ricesamplesThe values at the edges of the cluster are P-values (%) calculated over a multiscale bootstrap with 1000 resamples. Values on the left in red = au (approximate unbiased) P-values, and values on the right in green = bp (bootstrap probability) values. Clusters with au above 95% are highlighted in blocks suggesting high relatedness.

Comment [wa56]: Paddy.

Comment [wa57]: This statement affirms the statistical criteria please delete it here and transfer tothe statistical analysis section

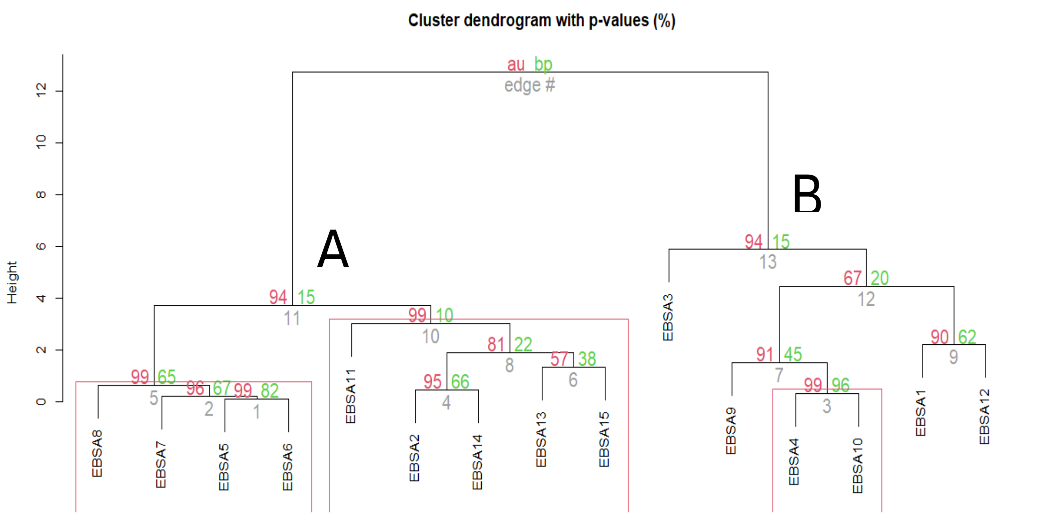


Figure 11: Cluster dendrogram with au/bp values (%) based on fatty acid compositions of cold water-soaked rice samples. the values at the edges of the cluster are p-values (%) calculated over a multiscale bootstrap with 1000 resamples. values on the left in red = au (approximate unbiased) p-values, and values on the right in green = bp (bootstrap probability) values. clusters with au above 95% are highlighted in blocks suggesting high relatedness.

4.0 Conclusions

This study analyzed the fatty acid composition of the local rice varieties of Abakaliki in both cold water-soakedand warm water-soaked paddies.and concluded that the fatty acids composition of warm water-soaked rice was higher than that of cold water-soakedrice in all samples. Therefore, warm water-soaking of paddy rice during rice processingis necessary for understanding the nutritional value and consumer preferences. The highest concentration of oleic acid witnessed in 'EBSA3' among warm water-soaked rice cultivars showed that heat could have been responsible for the trait being very noticeable compared to its counterpart among the cold water-soaked rice cultivars.

Comment [wa58]: This study investigated the impact of cold water-soaked and warm water-soaked paddy processing methods on the fatty acid content of local rice landraces in Abakaliki, Nigeria. The findings revealed that the fatty acid composition was higher in rice paddies soaked in warm water compared to those soaked in cold water. Among the warm water-soaked samples, the 'EBSA3' rice variety had the highest concentration of oleic acid, indicating that heat may have played a role. Therefore, the warm-soaked treatment of rice paddy improved the retention of nutritional value to meet consumer preferences.

Data Availability Statement

All data sets generated during and/or analyzed to support the findings of this study are phenotypic data and can be made available from the corresponding author on request.

References

Comment [wa59]: The guidelinesprovided by the journal should be strictly adopted.

Alaka IC, Okaka JC (2011). Physicochemical and milling characteristics of some selected locally processed rice in southeastern Nigeria. Journal of Science and Technology 17(1): 20-32.

Alaka IC, Ituma JOS, Ekwu FC (2011). Physical and chemical properties of some selected rice varieties in Ebonyi State. Nigeria Journal of Biotechnology 22: 40-46.

Byrd-Bredbenner C, Wardlaw GM, Moe G, Beshgetoor D, Berning JR (2009). Wardlaw's Perspectives in Nutrition: Perspectives in Nutrition-Eighth Edition. McGsoaked-Hill, New York. 686 Chenoweth, Stanley, and Jay.

Chukwu O, Oseh FJ (2009). Response of nutritional contents of rice (*Oryza sativa* L.) to parboiling temperatures. American-Eurasian Journal of Sustainable Agriculture 3(3): 381-387.

Clemente-Suárez VJ, Beltrán-Velasco AI, Redondo-Flórez L, Martín-Rodríguez A, Tornero-Aguilera JF (2023). Global Impacts of Western Diet and Its Effects on Metabolism and Health: A Narrative Review. Nutrients 15(12): 2749.

Danbaba N, Nkama I, Badau MH, Ukwungwu MN, Maji AT, Abo ME, Hauwawu H, Fati KI, Oko AO (2014). Optimization of rice parboiling process for optimum head rice yield: A response surface methodology (rsm) approach. International Journal of Agriculture and Forestry 4(3): 154-165

de Croos MDST, Pa´lsson S (2012). Present status of the multi-gear shrimp fishery off the west coast of Sri Lanka: gear-based species diversity and selectivity. Journal of Applied Ichthyology (2012): 1–15.

Ene CO, Wosene GA, Oselebe HO, Chukwudi UP, Okechukwu EC, Ozi FU, Menamo TM, Ene CK, Atugwu AI (2024). Selfing revealed potential for higher yield performance than backcrossing among tomato segregating populations of *Solanum lycopersicum* × *S. pimpinellifolium* crosses under tropical humid climate. Journal of Agriculture and Food Research 15: 100993.

FAOSTAT. (2020). World Food and Agriculture - Statistical Yearbook 2020. FAO. Retrieved

Gines BR, Gray J, Abugri DA (2016). Preliminary comparison of fatty acid composition(s) of selected commercial rice brands commonly consumed in North America. Austin Journal of Nutrition and Food Sciences 4(1): 1073.

Hu X, Fang C, Zhang W, Lu L, Guo Z, Li S, Chen M (2023a). Change in volatiles, soluble sugars and fatty acids of glutinous rice, *japonica* rice and *indica* rice during storage. LWT Food Science and Technology 174: 114416.

Hu X, Fang C, Lu L, Hu Z, Zhang W, Chen M (2023b). Dynamic changes in volatiles, soluble sugars, and fatty acids in glutinous rice during cooking. Foods 12(8): 1700

Jenning BH, Akoh CA (2009). Effectiveness of natural *versus* synthetic antioxidants in a rice bran oil-based structured lipid. Food Chemistry 114 (4): 1456-1461.

Juliano BO, Villarreal CP (1993). Grain quality evaluation of world rice. International Rice Research Institute, Philippines. Pg. 148.

Juwonlo M (2023). Nigerian farmers have displayed commendable resilience and flexibility due to ever-shifting climate dynamics. Climate scorecard: Nigeria News Brief and Action Alert

Kimura T, Bhattacharya KR, Ali SZ (1993). Discoloration Characteristics of Rice during Parboiling (I) Effect of Processing Conditions on the Color Intensity of Parboiled Rice. NogyoShisetsu. Journal of the Society of Agricultural Structures, Japan 24(3): 23-30.

Kromhout D, Menotti A, Bloemberg B, Aravanis C, Blackburn H, Buzina R, Dontas AS, Fidanza F, Giampaoli S, Jansen A, et al. (1995). Dietary saturated and trans fatty acids and cholesterol and 25-year mortality from coronary heart disease: the Seven Countries Study. Preventive Medicine 24(3): 308-15.

Law M (2000). Dietary fat and adult diseases and the implications for childhood rition: An Epidemiologic approach. American Journal of Clinical Nutrition 72 (5 Suppl): 1291S-1296S.

Mohidem NA, Hashim N, Shamsudin R, Che Man H (2022). Rice for Food Security: Revisiting Its Production, Diversity, Rice Milling Process and Nutrient Content. Agriculture 12(6): 741.

Oformata GEK Ed. (1975). Nigeria in maps: Eastern States. Ethiopia publishing Hons. Benin City, Nigeria. Pg. 146.

Oko AO, Ugwu SI (2011). The proximate and mineral compositions of five major rice varieties in Abakaliki, South-Eastern Nigeria. International Journal of Plant Physiology and Biochemistry 3(2): 25-27.

Oluremi OI, Solomon AO, Saheed AA (2013). Fatty acids, metal composition and physico-chemical parameters of Igbemo Ekiti rice bran oil. Journal of Environmental Chemistry and Ecotoxicology 5(3): 39-46.

Parnsakhorn S, Noomhorm A (2008). Changes in physicochemical properties of parboiled brown rice during heat treatment. Agricultural Engineering International: The CIGR e-journal 10. Manuscript FP 08 009. X: 1-20.

Sanni SA, Okeleye KA, Soyode AF, Taiwo OC (2005). Physicochemical properties of early and medium maturing and Nigerian rice vatieties. Nigeria Food Journal 23: 148-152.

Saraswathi V, Kumar N, Ai W, Gopal T, Bhatt S, Harris EN, Talmon GA, Desouza CV (2022). Myristic Acid Supplementation Aggravates High Fat Diet-Induced Adipose Inflammation and Systemic Insulin Resistance in Mice. Biomolecules 12(6):739.

Siri-Tarino PW, Sun Q, Hu FB, Krauss RM. (2010). Saturated fat, carbohydrate, and cardiovascular disease. American Journal of Clinical Nutrition 91(3): 502-9.

Suzuki R, Shimodaira H (2006). Pvclust: an R package for assessing the uncertainty in hierarchical clustering. Bioinformatics Applications Note 22(12): 1540–1542.

Verma DK, Prem Prakash Srivastav PP (2017). Proximate Composition, Mineral Content and Fatty Acids Analyses of Aromatic and Non-Aromatic Indian Rice. Rice Science 24(1): 21-31.

Wardlaw GM, Kessel MW (2002). Perspectives in nutrition. McGsoaked-Hill.

Zaplin ES, Liu Q, Li Z, Butardo Jr VM, Blanchard CL, Rahman S (2013). Production of high oleic rice grains by suppressing the expression of the OsFAD2-1 gene. Functional Plant Biology CSIRO 2013: A-I. d

Zhou C, Li B, Yang W, Liu T, Yu H, Liu S, Yang Z (2024). A comprehensive study on the influence of superheated steam treatment on lipolytic enzymes, physicochemical characteristics, and volatile composition of lightly milled rice. Foods 13(2): 240.

Zhou Z, Blanchard C, Helliwell S, Robards K (2003). Fatty acid composition of three rice varieties following storage. Journal of Cereal Science 37(3): 327-335.

A

B