

Effects of Packaging on Proximate and Mineral Compositions of Ndop Rice (Tox Variety) During Storage

Original Research Article

ABSTRACT

This study was conducted to investigate the pre and postharvest activities of rice stakeholders and to evaluate the influence of packaging on the proximate and mineral compositions of Ndop rice (TOX rice variety). A survey involving rice stakeholders was conducted in Ndop using a semi-structured questionnaire to gather information on the production, preparation, storage and handling practices of rice. It was found after the survey that, Ndop rice samples from UNVDA were stored in different packaging materials viz; polypropylene, nylon, rubber containers and paper bags at room temperature for two months. It was documented that 55% male and 45% female with the majority(63%) within the age category of 31-50 years are involved in Ndop rice postharvest management practices. Results also revealed that a majority (71%) of the respondents use polypropylene woven bags as packaging materials while 38% of respondents store rice for six months. Mice and weevils were reported as the key biotic factors affecting Ndop rice during storage. Furthermore, the results also showed that the moisture content (MC), fat, carbohydrate, ash and crude fiber contents decreased while protein increased across all the treatments during storage. Rice packed in paper bags had the lowest MC (10.17%), while rice in rubber containers had the highest MC (14.67%), at the end of the two months storage period. Rice packed in nylon bag had the highest protein content (14.11±0.71%). The mineral contents of Ndop rice decrease across all treatments after the second month of storage. The highest mineral retention (214.22±5.64 mg/100g for potassium) was observed in rice packed in paper bags. To maintain quality, paper bags or plastic buckets could be recommended as the best packaging materials for Ndop rice at the end of the second-month storage duration. This study contributes to food sufficiency and security by curbing postharvest food loss in Cameroon.

Keywords: Rice; Postharvest Loss; proximate composition; Mineral composition; packaging condition.

1. INTRODUCTION

Rice (*Oryza sativa*) is considered the best staple food among all cereals consumed by over 3 billion people, constituting over half the world's population [1,2]. Rice production is concentrated in Asia (~90% of total world production), with China and India being the largest single national producers and consumers of rice [3]. Because of its critical role in human nutrition, more rice must be produced annually to provide food for a growing world

population estimated to reach 10 billion by 2050 [4]. Rice is becoming a major cereal crop in Cameroon and is largely produced by subsistent smallholder farmers, mostly women on small plots. It is widely grown in the Ndop and Mbaw plains of the Northwest region; the Western region around Foubot, Tonga, and Santchou; the Central region extending to Makenene, and most importantly in the North (Lagdo area) and Far North (Yagua) regions of the country [5]. In Cameroon rice is produced in lowland and upland, both of which are rain-fed and irrigated across the country. In the year 2008, New Rice for Africa – (NERICA) varieties that are said to be adapted to various agro-ecological zones in the country were introduced using the participatory Varietal Selection (PVS) approach. In 2020, rice, paddy production for Cameroon was 328,503 tones. Though Cameroon rice and paddy production fluctuated substantially in recent years, it tended to increase through the 1971 - 2020 period ending at 328,503 tonnes in 2020 [6].

Nutritionally, rice is a rich source of carbohydrate (CHO); it contains a moderate amount of protein and fat and is also a source of vitamin B complexes such as thiamine (vitamin B1), riboflavin (vitamin B2), and niacin (vitamin B3) [7]. Minerals like calcium (Ca), magnesium (Mg), and phosphorus (P) are present along with some traces of iron (Fe), copper (Cu), zinc (Zn), and manganese [8]. The matured rice is categorized as grains that need preservation, including packaging after harvesting, before consumption by the final consumers. If improperly preserved, they can undergo a series of physicochemical reactions such as colour changes and oxidation during storage making them unfit for human consumption and reducing their market value. Rice is expected to have good shelf life due to the effect of low moisture which is sufficient to prevent spoilage. However, improper handling and packaging result in the limited shelf life of rice through microbial growth, enzymatic changes, and variation in moisture content. Packaging plays an important role in both the handling and storage of rice and the shelf life can be increased by using a proper packaging system.

Varieties of materials had been used in Cameroon for the packaging of rice. Rice is normally transported as break-bulk cargo in bags; usually, 20 – 25 kg woven propylene bags, allowing for easy handling and storage. However, bagged cargo is susceptible to several problems, including wet damage, tearing and theft, grain spillage from sacks and attacks by pests. Most farmers in Cameroon still use traditional storage facilities, called 'Hoka'. This kind of storage is not safe as it is made of palm leaves or plastic which are susceptible to pest and disease infestation. Furthermore, Low/medium gauge polyethylene, aluminum foil, polypropylene, and polyvinyl chloride are common packaging materials for food products due to their availability, low cost, and strength. However, little attempt has been made to evaluate the effects of packaging materials on the quality of milled rice [9]. To minimize postharvest losses of rice during storage, it is better to store the rice in moisture vapour proof packaging materials like polythene bags, aluminum foil, tin, or any sealed container to maintain the quality for a longer period. Minimizing rice losses in the supply chain could be one resource-efficient way that can help in strengthening food security, sustainably combating hunger, reducing the agricultural land needed for production, and rural development, and improving farmers' livelihoods. Therefore, this work sought to evaluate the effect of packaging materials and storage duration on the nutritional properties of Ndop rice. We propose the hypothesis that the duration and type of packaging material influence the quality of Ndop rice in storage.

2. MATERIAL AND METHODS

2.1. Selection of the Study Area

The study was conducted in Ndop located in the North-West of Cameroon. Ndop well-known for upland/highland rice production stands about 1,220m (4000ft) above sea level and is

located between latitude $5^{\circ} 37' N$ to $6^{\circ} 14' N$ of the equator and between longitudes $10^{\circ} 23' E$ to $10^{\circ} 33' E$ of the Greenwich Meridian (fig1). Ndop lies in the Western highland agro-ecological zone III with a monomodal rainfall distribution pattern. This subdivision has four rice-growing zones which are Bamunka, Bamali, Bambalang and Bamesseng. It has an average temperature of about $26^{\circ}C$ with an average maximum daily temperature of $27^{\circ}C$ and a minimum average of between $11^{\circ}C$ and $14^{\circ}C$ which fluctuates more rapidly than the maximum. **This area was purposively selected based on the intensity of rice production.**

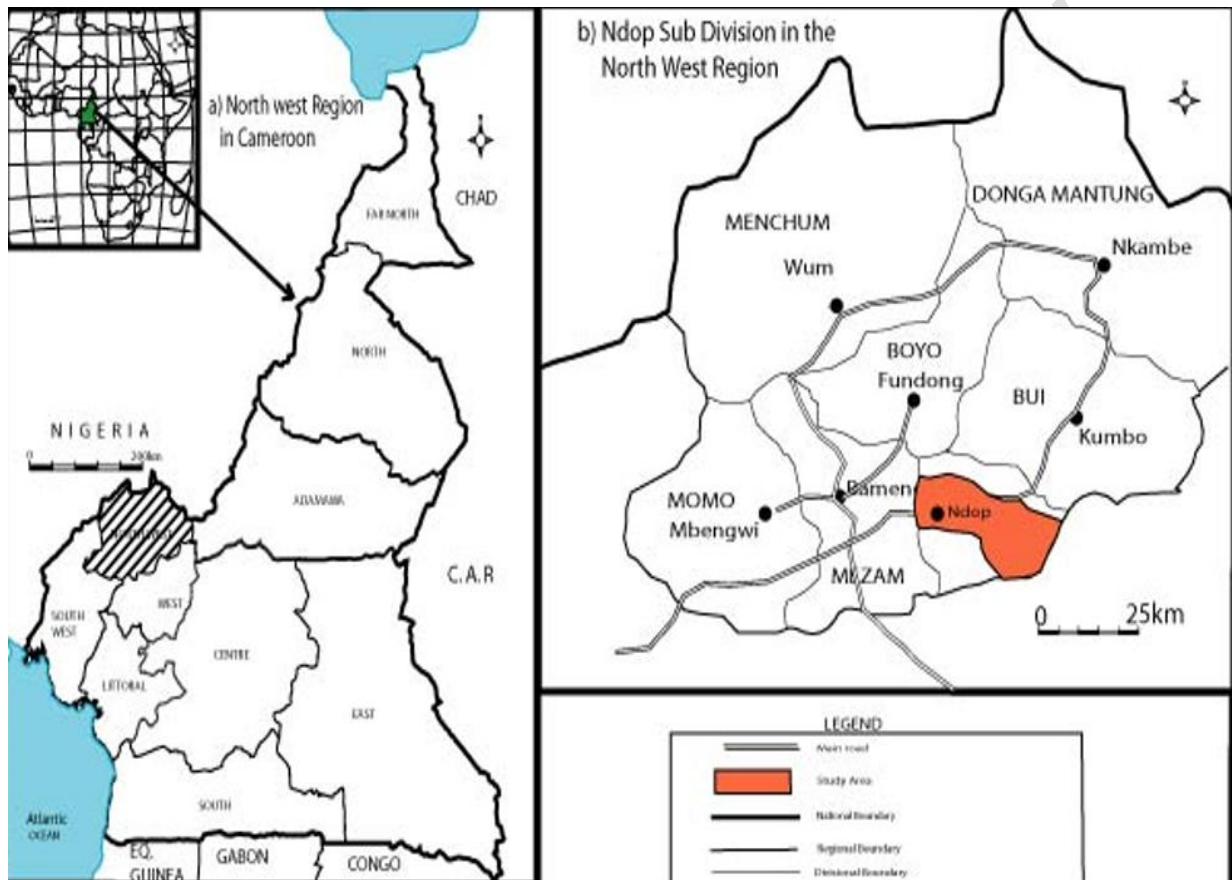


Fig. 1. Rice cultivation area in Ndop plain, Northwest Region, Cameroon. Source: Cameroon Geographical Review and National Institute of Cartograph

2.2 Determination of Rice Seed Production and Postharvest Practices

2.2.1. Survey Design and Administration

The survey on **stakeholders** (farmers, farmers/millers, millers only, traders) perception and knowledge of postharvest losses of rice was conducted in Bamunka. The study village was selected based on proximity to the existing large plain used for rice production and **the Upper Noun Valley Development Authority (UNVDA)**. **Before** the survey, a preliminary survey was made by meeting with **stakeholders** to develop a questionnaire with suitable information about farming practices and postharvest operations. During the survey, face-to-face interviews of 100 rice stakeholders chosen at random, were conducted. The

questionnaire included the following sections: demographic profile of the participants, farming characteristics, post-harvest operations and marketing characteristics of Ndop rice. The sampling frame comprised all rice stakeholders in the Ndop, Ngoketunjia division of the North-West. The sample population of 100 was obtained by applying the formula according to [10];

$$n = \frac{z^2 pq}{d^2} \dots \dots \dots \text{Equation 1}$$

Where:

n = The desired sample size

z = 1.96 (confidence level at 95%)

p = Proportion in target population estimated to have a particular characteristic (rice stakeholders (0.1))

q = 1-p (0.9)

d = Level of precision at 5% (standard value of 0.05).

2.2.2. Collection and Analysis of Data

For collecting data, personal visits were made to the house of sampled rice stakeholders. At the beginning of the interview, the aims and objectives of the study were explained to each stakeholder. The questions were asked in a very simple manner with an explanation of questions where necessary and the replies were recorded in the questionnaire. In achieving one of the objectives of the study, the coded data obtained from the filled questionnaires were entered into the Microsoft EXCEL worksheet and were classified, tabulated and analyzed to find out the frequencies and percentages of stakeholders' responses.

2.3. Collection of Raw Materials for Packaging and Storage of Rice Samples

A week-old hulled Ndop rice (TOX rice variety), obtained from 10 lots from UNVDA was used for the laboratory experiment to investigate the effect of packaging conditions on the proximate and mineral compositions of the rice samples.

2.3.1. Packaging and Storage of Rice Samples

A completely randomized design was used for the experiment on the storage of Ndop rice in different packaging materials. Four treatments were used and each was replicated thrice. Two kg of Ndop rice was packaged as follows: (1) Polypropylene bags, (2) nylon bags, (3) rubber containers and (4) paper bags for storage for two months at room temperature.

2.4. Proximate Analysis

The moisture, total ash content, crude fibre, crude protein (N x 6.25), crude fat and total energy content of samples were analyzed using the method described by the Association of Official Analytical Chemists [11]. Percentage carbohydrate content was calculated by using the difference method as shown in equation 2:

$$\%Carbohydrate = \%(protein + fat + Moisture + Ash) \dots \dots \dots \text{Equation 2}$$

2.5. Elemental Analysis

The macro and micro-elements (Na, K, Ca, Mg, Fe and Zn) were analyzed using the atomic absorption spectrophotometer (Perkin Elmer AA Analyst 700), flame atomic absorption spectrophotometer (Model Z5000, Hitachi, Japan) and UV spectrophotometer (Analytikjena SPECORD 205). Samples were digested using the wet ashing method with a mixture of perchloric acid and concentrated nitric acid (1:4 v/v), allowed to cool and filtered through No. 42 Whatman filter paper. The samples were each made up to 25mL with deionized water and each sample aliquot was then used to determine the elemental content with the atomic absorption spectrophotometer.

2.6 Statistical Analysis

Descriptive and inferential statistics were employed to analyze generated data. SPSS version 17 was used to analyze the responses on farmers' perception of postharvest losses. The descriptive statistics used included frequencies, percentages, mean, maximum and minimum values, and standard deviations. Experimental data recorded for the nutritional content in the different packaging materials were analyzed using ANOVA by Minitab version 18 and separation of treatment means was done using Turkey's HSD parametric multiple comparisons test ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1. Socio-demographic Profiles of Respondents

A total of 100 stakeholders participated in the survey on post-harvest practices of rice in Bamunka, Ndop. The demographic characteristics of the participants shown in Table 1 captured gender, age group, marital status, education level and household size. The study revealed that 55% of the respondents were males and 45% females. For the age category, most (32%) were between the ages of 41 to 50 years, 31% between 31 to 40 years indicating a young and productive population. Those that fell between 20 to 30 years were 27% and only less than 10% were above 51 years. Overwhelming majorities (72%) of the respondents were farmers and only 28% of the respondents indicated other occupations. Also, 48% of respondents recorded, were below the secondary level of education, 17% had secondary level of education, 8% did vocational studies and 17% had attained university level of education. Previous survey studies also showed a similar trend of a lower level of education among rice farmers and agree with the demographic profile of Ndop rice stakeholders [12, 13, 14].

Regarding farm sizes, a majority (53%) had farm sizes below 0.5 ha of land, 22% had farm sizes of 0.5 to 1 ha of land, 17% had between 1 to 2 ha of land and a few (8%) had above 2 ha of land. These results are similar to those of Mironka (2005) who stated that the landholding of the farmers in the study area ranged from 0.5 to 1.5 hectares. However, the results are different from those of Sheikh *et al.* [13] who reported that the average operational landholdings of the farmers in their study were more than 10 ha. The household size ranged from 4 to 7 (63%), 8-11 (22%), 7% had below 3 members and 8% had above 12 members. Most respondents were between ages 31 to 50 which showed that a large number of farmers belonged to middle or old age groups. These results are in tandem with previous scholarships [12, 14].

3.2. Rice Stakeholders Packaging and Storage Operations

The study showed that due to lack of access to modern storage facilities, farmers stored rice in different storage materials like polypropylene woven bags, polypropylene woven bags/nylon bags, nylon and rubber buckets. The results presented in figure 1 show that 71% of the respondents package their rice in polypropylene woven bags, 18% in both Nylon and polypropylene woven bags, 2% in Nylon and 9% in buckets. The main packaging materials used for Ndop rice are polypropylene woven bags. This might be attributed to its availability and affordability, easy handling and storability.

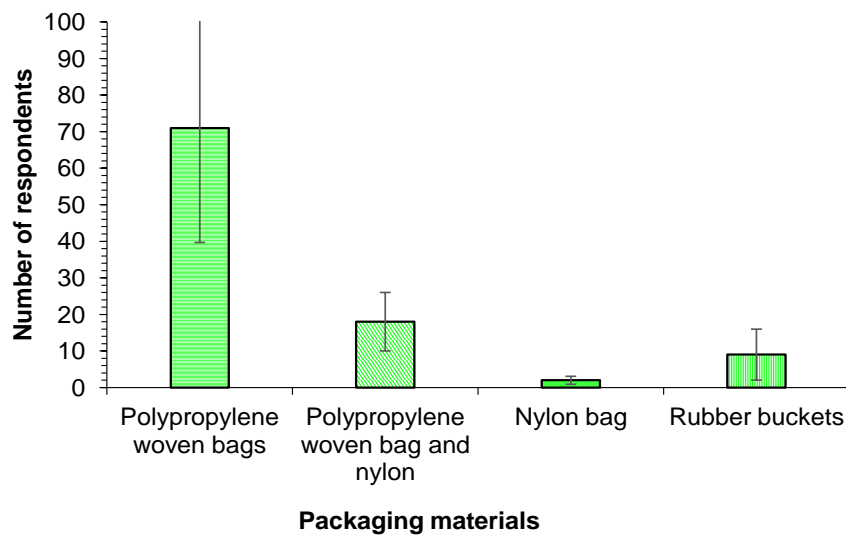


Fig. 2. Distribution of respondents on types of materials use in Ndop rice packaging

With respect to challenges relating to rice storage and packaging, 34% of respondents reported not having any major challenges with the Ndop rice packaging materials, 31%, 21% and 14% of respondents reported mice, short shelf life and the high cost of packaging materials as major challenges. Most reported rodent infestation which could lead to pest and disease infestation and contamination with excrement reducing the quality of rice. Similar findings have been reported by [15] in some selected flood-prone areas under Bhola district in Bangladesh where rice stored in Gunny and Plastic bags were susceptible to damage by the attack of microorganisms, insects and rodents and caused considerable damage and loss.

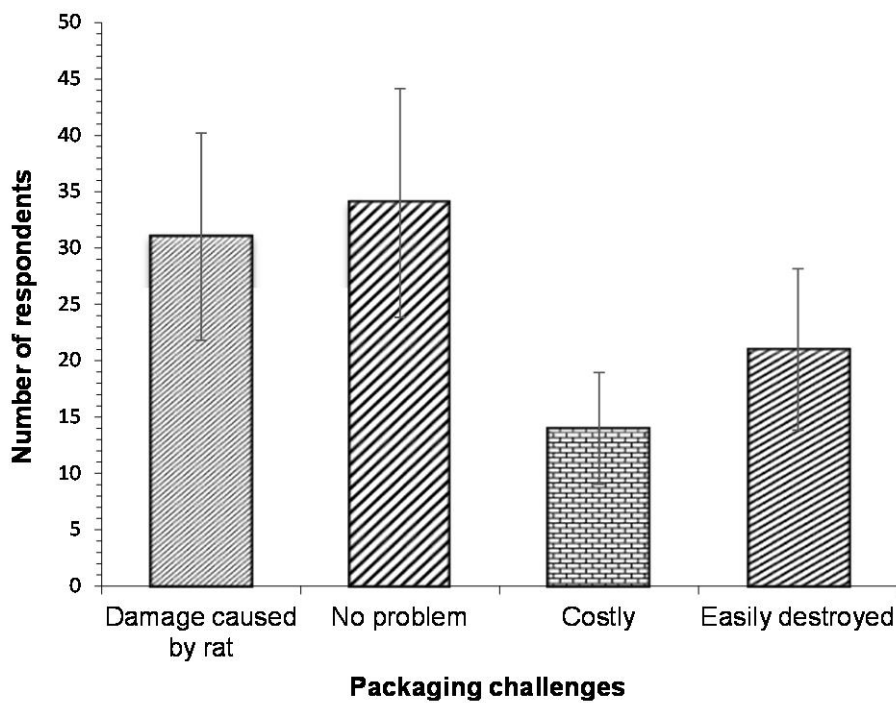


Fig. 3. Distribution of respondents according to challenges faced in Ndop rice packaging

Figure 4. reveals that 38% of respondents store rice for zero to six months, 33% for 7 to 12 months and 29% store it for 12 to 18 months. 86% store primarily for sell and consume the excess while only 14% store primarily for consumption and sold when the need arises. A similar result was revealed by [16] who reported that farmers sell rice immediately after harvest because of indebtedness and/or poor storage conditions.

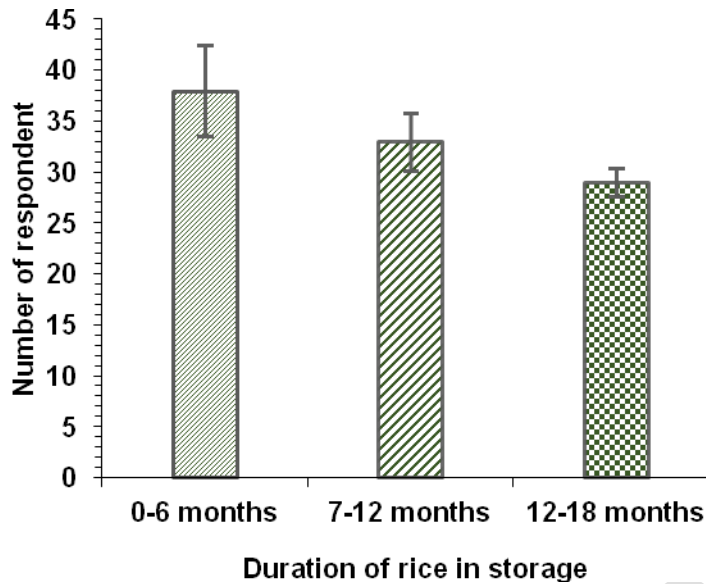


Fig.4. Distribution of respondents according to the storage duration of Ndop rice

Regarding the challenges encountered during storage, it was noted that 50% of respondents lacked good storage conditions for rice, 20% recorded no challenges in storage, while 13% reported the lack of labour for constant monitoring and drying as a major challenge in storage (Fig. 5). 10% reported a lack of durable storage materials as a major storage challenge while 7% reported theft during storage.

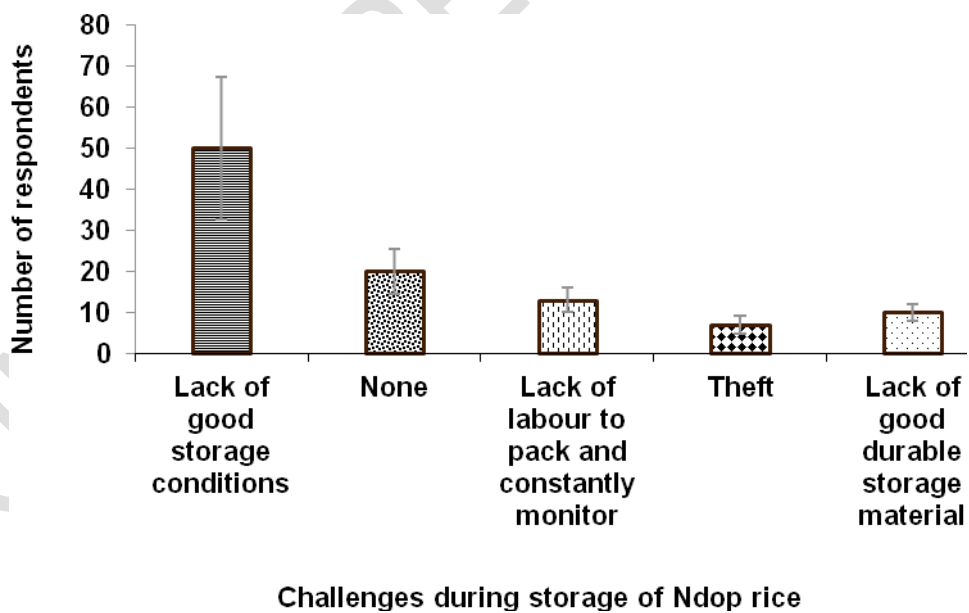


Fig. 5. Distribution of respondents according to the challenges faced in rice storage

Table 1. Socio-demographic Characteristics of Ndop rice Stakeholders

Characteristics	Count	Percentage (%)	Characteristics	Count	Percentage (%)
Gender			Occupation		
Male	55	55	Farmer	72	72
Female	45	45	others	28	28
Age group			Farm size		
20-30	27	27	<0.5	53	53
31-40	31	31	0.5-1.0	22	22
41-50	32	32	1.0-2.0	17	17
51-60	7	7	2.0-3.0	4	4
>60	3	3	4.0-5.0	2	2
Marital status			.5.0	2	2
Single	22	22	Farming experience		
Married	78	78	0-10	38	38
Level of education			11 to 20	37	37
No primary	10	20	21 to 30	15	15
Primary	28	28	31 to 40	10	10
Secondary	17	17			
High school	20	20			
Vocational	8	8			
University	17	17			
Household size					
<3	7	7			
4-7	63	63			
8-11	22	22			
>12	8	8			

Table 2. Effect of packaging materials and storage duration on the proximate composition of Ndop rice

Months of storage	Packaging material (%)	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude lipid (%)	Crude Fibre (%)	Carbohydrate content (%)	Energy content (%)
Month 0	No packaging	11.31 ^a ±0.12	2.29 ^a ±0.05	11.31 ^a ±0.12	1.64 ^a ±0.01	2.96 ^a ±0.14	69.72 ^a ±0.19	341.86 ^a ±6.60
Month 1	Polypropylene woven bag	13.44 ^a ±0.34	2.06 ^b ±0.05	13.55 ^a ±1.49	1.63 ^a ±0.03	2.52 ^b ±0.11	65.21 ^c ±1.26	333.72 ^b ±5.22
	Nylon bag	13.62 ^a ±0.50	1.70 ^b ±0.43	13.13 ^a ±1.26	1.57 ^b ±0.00	2.01 ^b ±0.20	65.10 ^c ±1.02	336.00 ^b ±6.80
	Plastic bucket	10.95 ^b ±1.14	1.66 ^b ±0.20	12.43 ^a ±1.00	1.63 ^a ±0.01	2.32 ^b ±0.20	69.80 ^b ±1.07	347.62 ^b ±6.79
	Paper bag	10.96 ^b ±1.75	1.94 ^b ±0.05	12.31 ^a ±1.49	1.63 ^a ±0.10	2.83 ^b ±0.10	68.68 ^b ±2.09	346.61 ^b ±4.52
Month 2	Polypropylene woven bag	14.02 ^c ±0.72	1.93 ^b ±0.12	14.10 ^c ±1.02	1.54 ^b ±0.12	2.44 ^b ±0.71	63.32 ^d ±1.12	324.58 ^a ±4.78
	Nylon bag	14.02 ^c ±0.22	1.31 ^c ±0.20	14.11 ^c ±0.71	1.54 ^b ±0.01	1.58 ^b ±0.61	63.07 ^d ±1.05	330.58 ^c ±4.98
	Paper bag	9.37 ^c ±2.76	1.82 ^b ±0.11	13.06 ^b ±0.55	1.61 ^b ±0.01	2.88 ^b ±0.91	64.69 ^b ±1.06	349.57 ^b ±2.46

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscripts in the same column differ significantly ($p < 0.05$)

Table 3. Effect of packaging materials and storage duration on the mineral content of Ndop rice (mg/100g)

Months of storage	Packaging material	Fe(Mg/100g)	Na(mg/100)	K(mg/100g)	Ca(mg/100g)	Mg(mg/100g)	Zn(mg/100g)
Month 0	No Packaging	0.20 ^a ±0.03	6.14 ^a ±0.38	258.60 ^a ±0.46	7.56a±0.60	30.35 ^a ±0.57	5.50 ^a ±0.46
Month 1	Polypropylene woven bag	0.06 ^b ±0.02	5.65 ^a ±0.03	254.20 ^a ±2.14	6.38b±0.35	29.52 ^a ±0.40	2.97 ^b ±0.31
	Nylon bag	0.05 ^b ±0.02	5.45 ^a ±0.03	260.20 ^a ±1.64	6.99 ^{ab} ±0.26	28.42 ^a ±0.40	3.04 ^b ±0.15
	Plastic bucket	0.02 ^b ±0.01	5.74 ^a ±0.04	210.20 ^b ±2.89	6.78 ^{ab} ±0.26	29.55 ^a ±0.45	3.67 ^b ±0.15
	Paper bag	0.08 ^b ±0.03	5.69 ^a ±0.04	260.50 ^a ±1.32	6.87 ^b ±0.35	19.11 ^a ±0.90	4.52 ^b ±1.80
Month 2	Polypropylene woven bag	0.00 ^b ±0.00	4.65 ^b ±0.05	230.40 ^b ±0.35	4.977 ^b ±0.03	26.40 ^b ±0.20	2.51 ^b ±0.10
	Nylon bag	0.03 ^b ±0.01	4.77 ^b ±0.01	211.21 ^d ±3.54	5.85 ^b ±0.05	10.21 ^c ±0.20	2.87 ^b ±0.45
	Plastic bucket	0.00 ^b ±0.00	4.26 ^b ±0.10	191.25 ^c ±5.52	5.86 ^b ±0.04	16.97 ^c ±0.50	3.40 ^b ±0.30
	Paper bag	0.02 ^b ±0.01	4.45 ^b ±0.05	214.22 ^d ±5.64	6.10 ^c ±0.36	16.03 ^d ±0.50	2.96 ^b ±0.25

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscripts in the same column differ significantly ($p < 0.05$)

3.3 Proximate Composition and Calorie Contents of Packaged Rice

The influence of the packaging materials on the proximate composition of rice is presented in Table 2. ANOVA shows that **package** had a significant impact on the proximate composition of the **Ndop rice** ($p < 0.05$). An increase in moisture content during the storage period was observed in rice Polypropylene woven bags and Nylon while a decrease in moisture content was observed in rice stored in rubber buckets and paper bags during storage. Rice packed in Polypropylene woven bags and Nylon had the highest moisture content ($14.02 \pm 0.72\%$ and $14.02 \pm 0.22\%$ respectively) while rice packed in rubber buckets and paper bags had the lowest moisture content at the end of the **two** months of storage ($9.19 \pm 2.85\%$ $9.37 \pm 2.76\%$ respectively). Most food grains including rice have a hygroscopic characteristic and thus when exposed to various conditions, the moisture content will move from the grains to the surrounding, or vice versa until there is a characteristic balance (or equilibrium) between the moisture they contain and the water vapour in the surrounding conditions [17]. This finding corresponds with results revealed by [18] who reported that sorghum seeds stored in hermetic bags exhibited little change in MC while woven bags facilitated moisture equilibration between the grains and ambient environment [18]. **MC** in food can have a significant impact on a product's quality and shelf life [19]. High moisture enhances microbial growth and therefore shortens the shelf life of stored rice [20]. A significant decrease in the ash content of the rice was observed in all the packaging materials during the whole storage period. The decrease was in the order, **of polypropylene woven bag ($1.93 \pm 0.12b\%$) > paper bag ($1.82 \pm 0.11\%$) > nylon bag ($1.31 \pm 0.20c\%$) > plastic bucket ($1.20 \pm 0.19\%$)** at the end of two months of storage when compared to the initial ash content ($2.29 \pm 0.05\%$). This observation correlates with the report of [21] who reported that ash content was reduced in stored Paddy during a storage period of 18 months. This result also corroborates the report of [22] who reported that ash content reduced from 530-520mg/100g to 490-480mg/100g in stored Chia seeds during a storage period of 10 weeks. The observations on crude protein influenced by packaging materials showed significant differences in two months of storage (Table 2). **Among the packaging materials, polypropylene woven bags and nylon had** significantly higher crude protein, while, significantly lower crude protein was observed in plastic buckets and paper bags. The increase in protein content could be attributed to the fact that as carbohydrates are being utilized in respiratory processes, protein increases, proteolytic enzymes produced by fungi can modify the protein in grains by hydrolyzing it into polypeptides and amino acids. The result is contrary to that presented by Naik and Chetti, [21] who revealed that **crude protein content** was decreased with advancement of storage period (18 months) among all the packaging materials viz; vacuum-packed bags (C1), polythene bags (C2), cloth bags (C3) and gunny bags (C4). The observations on fibre content as influenced by packaging materials differed significantly between treatments during the first month of storage. However, there was no significant difference in the crude fiber content during the second month across all packaging materials. The decline in the fibre content suggests the action of the enzymes produced by the fungi present in the grain. [23] reported a range of crude fibre values ($0.29 - 0.73\%$). The content of fibre for rice stored in different packaging materials varieties fell above 1.00% which is above this range. The data on carbohydrate content as influenced by different packaging conditions varied significantly between treatments during storage. Among the packaging materials, the carbohydrate content was significantly higher in Plastic buckets and paper bags while lower in polypropylene woven bags and nylon bags. [24], revealed that respiration involves high consumption of simple sugars and both respiration and degradation processes are intensified during later stages of storage. The data on fat content as affected by packaging materials during two storage presented in Table 2 revealed significant differences between packaging materials during the first month of storage. However, there was no significant difference in the crude fiber content during the second month across all packaging materials. The results are in agreement with earlier findings by [8], where they obtained fat content in the range of $0.5-3.5\%$ from five rice varieties. The decline in the fat content of the rice **maybe because** most fungi have high lipolytic activity and fats and oils in grains are readily broken down into free fatty acids and partial glycerides which in turn led to the loss **of** the nutrients. Therefore, the reducing action of the lipolytic enzymes produced by the fungi may thus be responsible for fat decline. The data on total energy content as influenced by different packaging conditions differed significantly between treatments. For the first month of storage, among the packaging materials, the total energy content was significantly higher in rubber buckets and paper bags while significantly lower in polypropylene woven bags and nylon bags. By the second month of storage, the total energy content stored in polypropylene woven bags, nylon bags and rubber buckets reduced while that of paper bags increased. Food energy values were appreciably different among all the

treatments. The total energy content differed significantly in the order plastic bucket>paper bag>nylon>polypropylene woven bag. Similar results were observed in rice by [25] who revealed that NERICA-2, NERICA-1 and Digang rice varieties provide 351.58 ± 3.11 kCal/100g, 348.31 ± 0.30 kCal/100g and 345.61 ± 0.72 kCal/100g of energy respectively.

3.4. Mineral Composition

In this study, the major minerals in the rice samples are presented in Table 3. A significant decrease in the mineral composition of the rice was observed in all the packaging materials during storage. The mean concentration in mg/100mg of the minerals analyzed in the rice sample is in the following order: K>Mg>Ca>Na>Zn>Fe at the end of two months of storage for all packaging material. The reduction in mineral contents confirmed the decrease in ash contents of the rice. Potassium was found to be very dominant in the rice samples than other mineral elements. The value obtained for K for all was comparable to that obtained by [26], (216-268mg/100g of rice). Magnesium was the second most abundant element found in the rice samples. Statistical analysis showed that there was a significant difference in magnesium content among the rice samples packaged in different packaging materials. Magnesium content was dominant in rice samples stored in a Polypropylene woven bag with a concentration of 26.40 ± 0.20 mg/100g compared to rice samples stored in Nylon (10.21 ± 0.20 mg/100g). The values obtained for minerals are slightly lower than the values obtained by Ephraim *et al.*, [26] (30.21mg/100g to 40.32mg/100g). Packaging materials had a significant impact on the calcium content of rice during storage ($p < 0.05$). Calcium contents obtained in this study after storage across all packaging materials were lower than the range obtained by [27], who reported a calcium content of 24 mg/100g and 60 mg/100g in raw and parboiled white rice, respectively. Mineral elements like zinc and iron are very crucial for plant growth and human health, and play a key role in various physiological and biochemical processes. Results pertaining to zinc and iron content during the study showed a decrease during the storage period across all packaging materials. Among the containers, the decrease in iron and zinc content was very less in the Nylon bag (0.03 ± 0.01 mg/100g) and plastic bucket (3.40 ± 0.30 mg/100g) respectively compared to other packaging materials throughout the storage period.

4. CONCLUSION

Rice is one of the most widely consumed crops in Cameroon and is relevant to the country's economic development and GDP. Despite the huge amount of rice produced in the country, the poor quality of the locally processed rice and other challenges has continually encouraged the importation of high-quality well packaged milled rice to satisfy the tastes and preferences of Cameroonians. Adequate and proper care of rice during storage and the type of packaging material could be important factors to be considered in establishing the shelf-life stability and maintaining the nutritional quality of rice. Results from the survey revealed that polypropylene woven bag is the most used packaging material followed by nylon bags and plastic buckets to store Ndop rice for a period of 6 to 12 months and most for sale. The effects of packaging materials on the proximate and mineral composition of rice were investigated and the hypothesis accepted that it influences rice quality and shelf life. The proximate composition of rice was affected by packaging conditions. The results of this study showed that plastic buckets and paper bags retained the nutritional qualities of the stored produce better than the polypropylene woven bags and nylon. The results of the current study may be useful in relation to the selection of packaging materials that can be used for the storage of Ndop rice. This will contribute to postharvest food loss reduction and food security in Cameroon.

REFERENCES

1. Folorunsho AA, Omoniyi SA, Habeeb AS. Proximate composition and sensory acceptability of snacks produced from broken rice (*Oryza sativa*) flour. *Amer. J. Food Nut.* 2016; 6(2): 39-43.
2. Hashmi MI, Tianlin JS. Mineral contents of some indigenous rice varieties of Sabah Malaysia. *Int. J. Agric., Forestry and Plantation.* 2016; 2(2): 31-33.
3. Verma, DK, Mohan M, Prabhakar PK, Srivastav PP. Physico-chemical and cooking characteristics of Issue Azad basmati. *Int. Food Res. J.* 2015; 22(4): 1380-1389.
4. IRRI. Trends in global rice consumption. *Rice Today*, January – March; 2013. Available: irri.org/rice/trends-in-global-rice.
5. MINADER (Ministry of Agriculture for Rural Development). National Strategy for Rice Growing in Cameroon, MINADER; 2009.
6. Knoema Enterprise. Rice Paddy Production in Cameroon; 2020. Available:<https://knoema.com/atlas/Cameroon/topics/Agriculture/Crops-Production-Quantity-tonnes/Rice-paddy-production>
7. Chaudhari PR, Tamrakar N, Singh L, Tandon A, Sharma D. Rice nutritional and medicinal properties: A review article. *Journal of Pharmacognosy and Phytochemistry.* 2018;7(2): 150-156.
8. Oko AO, Ugwu SI. The Proximate and Mineral Compositions of Five Major Rice Varieties in Abakaliki, South-Eastern Nigeria. *International Journal of Plant Physiology and Biochemistry.* 2010; 3(2): 25-27.
9. Adebowale, A., Owo, H., Sobukola, O., Obadina, O., Kajihousa, O., Adegunwa, M., Sanni, L., and Tomlins, K. Influence of storage conditions and packaging materials on some quality attributes of water yam flours. *Cogeni food and Agriculture*, 2017;(3): 1385130
10. Fisher LD. self-designing clinical trials. *Statistics in medicine.* 1998; 17:1551-1562
11. AOAC. Association of Official Analytical Chemist. Official Method of Analysis of AOAC International, 19th ed., Gaithersburg MD, USA: AOAC International; 2012.
12. Mironga JM. Effect of farming practices on wetlands of Kissii district, Kenya. *Appl. Ecol. Environ. Res.* 2005;3(2):81-91.
13. Sheikh AD, Mahmood MA, Bashir A, Kashif M. Adoption of rice technological package by the farmers of irrigated Punjab. *J. Agric. Res.* 2006; 44(4):341-352.
14. Heong KL, Escalada MM, Huan NH, Ky Ba VH, Quynh PV, Thiet LV, Chien HV. Entertainment-education and rice pest management: A radio soap opera in Vietnam. *Crop Prot.* 2008; 27:1392-1397.
15. Hasan MK, Abedin MZ, Islam T, Rahman MZ. Traditional rice storage facilities and options for safe storage: A study in some selected flood-prone areas under Bhola district. *Journal of the Bangladesh Agricultural University.* 2015; 13(1): 125–130.

16. Abedin, MZ, Rahman, MZ, Rahman, MM. Traditional rice storage structures and in-store losses: An assessment on selected upazilas under Rangpur district. *Bangladesh Journal of Agricultural Engineering*. 2009; 20 (1&2): 11-23.
17. Razak NA, Hamid NA, Shaari AR. Effect of storage temperature on moisture content of encapsulated *Orthosiphon stamineus* spray-dried powder AIP Conference Proceedings 2030, 020194 2018; <https://doi.org/10.1063/1.5066835>
18. Williams SB, Murdock LL, Baributsa, D. Sorghum seed storage in Purdue Improved Crop Storage (PICS) bags and improvised containers. *J. Stored Prod. Res.* 2017;72, 138–142.
19. Li M, Ma M, Zhu K-X, Guo X.-N, Zhou HM. Critical conditions accelerating the deterioration of fresh noodles: a study on temperature, pH, water content, and water activity. *Journal of Food Processing and Preservation*. 2016; <https://doi.org/10.1111/jfpp.13173>
20. Weinberg ZG, Yan Y, Chen Y, Finkelman S, Ashbell G, Navarro S. The effect of moisture level on high moisture maize (*Zea mays* L.) under hermetic conditions—in vitro studies. *Journal of Stored Products Research*. 2008; 44(2): 136–144.
21. Naik DS, Chetti MB. Influence of Packaging and Storage Conditions on Proximate Composition of Paddy, *Int. J. Pure App. Biosci.* 2017; 5(6):1632-1639 doi: <http://dx.doi.org/10.18782/2320-7051.3036>
22. Ashura, K, Leonard M, Oscar K, Lilian D. Effects of Drying, Packaging Conditions and Storage Time on Proximate Composition of Chia Seeds (*Salvia hispanica*). *Tanzania Journal of Science*. 2021; 47(1): 258-267
23. Shayo NB, Mamiro P, Nyaruhucha CNM, Mamboleo T. Physicochemical and grain cooking characteristics of selected rice cultivars grown in Morogoro. *Tanzania Journal of Science*. 2006; 32(1): 29-35.
24. Sanchez-Mata MC, Camara M, and Diez-Marques C. Extending shelf life and nutritive value of green beans (*Phaseolus vulgaris* L.) by controlled atmospheric storage: micronutrients. *Food Chem*, 2003b; 80: 315–318.
25. Guy E, Emmanuel A, Amankwah, John B. Proximate composition, mineral nutrients and functional properties of Digang, NERICA-1 and NERICA-2 rice varieties from Ghana *Global Advanced Research Journal of Agricultural Science*. 2019; 8(6): 207-21300.
26. Ephraim V, Frank C, Samson S, Timothy Tywell M. Proximate Composition, Mineral Composition and Phytic Acid in Three Common Malawian White Rice Grains. *Malawi Journal of Science and technology*. 2020; 12 (1): 87-108.
27. Verma DK, & Shukla K. Nutritional Value of Rice and their Importance. *Indian Farmers" Digest*. 2011; 44(1): 21-2