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Contribution of the triple hermetic bag in the preservation of locally processed cereal and legume products in Niger

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ABSTRACT

Cereals and legumes constitute the staple foods in both urban and rural areas, and the main cereals and legume products in the Sahel region are millet, sorghum, maize, and cowpea. The small-scale processors of those products are facing storage and good packaging challenges. Triple hermetic bag technology is effective for the conservation of many stored grains against insect spoilage in Africa and around the world. This study aimed to examine the performance of the high-density polyethylene Purdue Improved Cowpea Storage (PICS) bags (HDPE, 80 microns thick) for the preservation of processed cereals (broken corn, millet pellet, and sorghum *dagué*) and legume (broken cowpea) products against insects of storage. In addition, the impact of this technology on the physical and functional parameters of the processed products (moisture content, pH, water-holding capacity, oil-holding capacity, and bulk density) after 6 months of storage was carried out. *Rhizopertha dominica* was revealed to be the damaging storage pest in the product of millet pellet and broken corn with the average number of live insects of 121.33 and 0.66, respectively, in experimentally designed bags. Significant differences ($P < 0.01$) and ($P < 0.01$) are found among the results of functional and physical properties tested on these processed products, using PICS bags versus other storage types of bags. The use of triple hermetic bag technology for storage of processed cereals and legume products has shown protection against damaging insects and preserved their physical and functional properties qualities.

1. INTRODUCTION

Food production is mainly based on cereals which constitute the staple food in both urban and rural areas, and the main cereals produced in Sahel are millet (*Pennisetum glaucum* [L.]), sorghum (*Sorghum bicolor* [L.]), and maize (*Zea maize* [L.]) [1]. Followed by the production of cowpea (*Vigna unguiculata* [L.]), a considered legume as a cash crop; despite its diversity, Niger is still a major country in its agricultural production. Indeed, these cereals and legumes are part of the daily diet of the population of Niger. Hence, the most consumed grains of these cereals and legumes are products from millet, sorghum, and cowpea, including groundnuts. Food loss occurs during the production, post-harvest, and processing phases in the food supply chain [2]. These post-harvest losses represent a challenge mainly for the countries of sub-Saharan Africa where the action of insect pests of cereals and legumes can completely destroy in short time, stocks intended for food and even seeds if no protection is not provided.

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The problems that food producers in the Sahel encounter during the post-harvest phase of agricultural products have long been neglected and confused with those related to production. However, post-harvest losses are increasingly increasing because the traditional storage and processing technologies implemented are generally inadequate with risks of infestation of stored products [3]. Estimates of the prevalence of moderate or severe food insecurity in 2019 Niger and West Africa are 56% and in the world 30% (FAO, 2020) [4]. Indeed, there are countries in the Sahel region where food processing technology still has a long way to go; willingly, many are trying to establish, some small processing scale industries despite difficulties [5,6]. The technologies used for storage are, among others: Polypropylene bags, the use of hermetic storage tools such as silos and metal drums, plastic or metal canisters, and PICS bags. These hermetic storage and preservation structures have been much more recommended to producers/processors to minimize the loss of stored products (Pauer *et al.*, 2019) [7,8]. However, several constraints affect the production of processed cereal-based and cowpea products; one of the main constraints is insect attack by pests. In addition, these processing units are experiencing problems linked to the storage of their food products, they do use low-quality plastic bags for packaging; though, less accessible and efficient because it is easily punctured by insects (*Tribolium castaneum, Rhizopertha dominica,* etc.). Indeed, in the Sahel, few studies focused on the pests of processed foods products of such; yet there are listed of insects on agricultural products such as *Sitophilus oryzae*, *Trogoderma granarium,* and *R. dominica* [9-11]. Insects are among the factors responsible for the depreciation of the market value according to the processing units. Packaging can be of strategic importance to those small and medium-sized enterprises in the Sahel, as it can be a key to competitive advantage in the food industry.

The principal roles of food packaging are to protect food products from outside influences and damage, to contain the food, and to provide consumers with ingredient and nutritional information [12,13]. Previous studies have shown that the packaging can influence the organoleptic quality of the processed product over time [14,15]. The types of food packaging used in Niger cannot compete with those of imported products and may not guarantee the safety of the product against attack by insects or maintain the organoleptic quality of processed products. Although to reduce post-harvest losses of products, Purdue Improved Cowpea Storage (PICS) bag (HDPE, 80 microns thick) technology has been proven effective on various agricultural products [16-18]. The PICS bags consist of three plastic bags: Two high-density polyethylene 80 mm bags and one surrounded by the second; both are surrounded by a third woven polypropylene bag. The PICS bag reproduces the conditions of hermetic storage [19]. Therefore, the present work aimed to test the tri-bagging technology (PICS) on the preservation of processed products based on millet, sorghum, maize, and cowpea. Within this framework, the research is to show the performance of packaging for preserving the organoleptic quality of these processed food products and reducing the damage caused by storage insects through the functional and physical properties test on these processed products.

2. MATERIALS AND METHODS

These processed cereals and legume products (broken corn, broken cowpea, millet ball, and *dagué* of sorghum) were selected for experimentation in accordance with responses obtained through a conducted survey (data not shown) addressed to processors and product vendors. Some of these processed products appear to be easily attacked by insect pests and others are the most purchased products. Samples were purchased from the local market, in Maradi, Niger. All analyses were carried out on a dry weight basis and all the reagents used are of analytical grade.

2.1. Experimental Design

Each treatment consisted of six (6) repetitions of 400 g with each of the products, and samples were treated in three different conditions (PICS, selling bag, and ordinary bag). The following abbreviations are used to designate the products preserved with the three treatments (broken corn kept in PICS bags [80 µm thickness], broken corn kept in sales bags [60 µm thickness], broken corn kept in ordinary bags [50 µm thickness], broken cowpea stored in the PICS bag, broken cowpea stored in the sales bag, broken cowpea stored in the ordinary bag, millet pellet stored in PICS bags, millet pellet stored in the sales bag, millet pellet kept in the ordinary bag, sorghum *degué* [granules from process sorghum flour] kept in the PICS bags, sorghum *degué* kept in the sales bag, sorghum *degué* kept in the ordinary bag). The number of punctures and abrasions on the bags was followed by the count of the number of living insects; then, the dead insects were also numbered.

2.2. Moisture Content

The moisture content of the sample was determined using the halogen drying method. At the start of the measurement, the analyzer determines the weight of the product, the product is then quickly heated by the integral halogen desiccation unit, and the water vaporized (HR73 or HG53 Halogen Moisture Analyzer from METTLER TOLEDO). During this operation, the device continuously determines the weight of the product and displays the results after drying the percentage of moisture content on the screen [20].

2.3. pH

The pH was determined by taking a 10g sample and diluted in 100 mL of distilled water. The mixture was macerated for 30 min, and then, 10 mL of the supernatant was filtered to carry out the pH measurement using pH meter [21].

2.4. Water Retention Capacity

A 0.5 g sample was mixed with 5 mL distilled water 10 mL measuring cylinder and kept for 24 h; then, the supernatant was decanted. The initial weight of the sample after pouring the sample was noted to be Wi = Weight of the empty tube + weight of the weighed sample [22].

The water retention capacity is given by the following formula:

$$RC = We - Wi$$

Where
Wi: Weight of the initial sample in g
We: Weight of the sample after 24 h in g
RC: Water retention capacity in g

2.5. Oil Absorption Capacity

The oil absorption capacity (OAC) of the sample (0.5 g) was mixed with 5 mL *Balanites aegyptiaca* oil and then centrifuged at 3000 × g for 10 min (80–2 15/20 mL Electronic Lab Centrifuge Machine, Jiangsu, China) and oil released after centrifugation was massed and expressed as (mL/g) OAC capacity, according to Sofi *et al.* [22] with some modifications.

2.6. Swelling Volume

A 1g sample was mixed with 10 mL distilled water 10 mL measuring cylinder and kept for 24; then, the supernatant was decanted. The volume level marked after 24 h was considered as the total volume (TV) of the sample [23]. The volume of the swelling of the products is determined by the following formula:

$$SV\ (g/Cm^3) = TV/Wi;$$

Where
TV: Total volume of the sample after 24 h in mL
Wi: Initial sample weight (1g).

2.7. Bulk Density

A 15 g sample was weighed and poured into a 100 mL measuring cylinder; then, the tube was banged 40 times on a smooth table. The final volume of the sample is noted after the 40 steps [24], the bulk density was given by the following formula:

$$BD\ (g/Cm^3) = We/Vp;$$

Where
BD: Bulk density
We: Sample weight (15 g)
Vp: Volume after 40 steps (Cm^3)

2.8. Statistical Analysis

All experiments were performed at least in triplicate. One-way analysis of variance (ANOVA) was performed and significant differences in mean values were evaluated by Duncan's multiple range test. The least significant difference was taken at ($P < 0.05$) and ($P < 0.01$) using IBM-SPSS version 20.

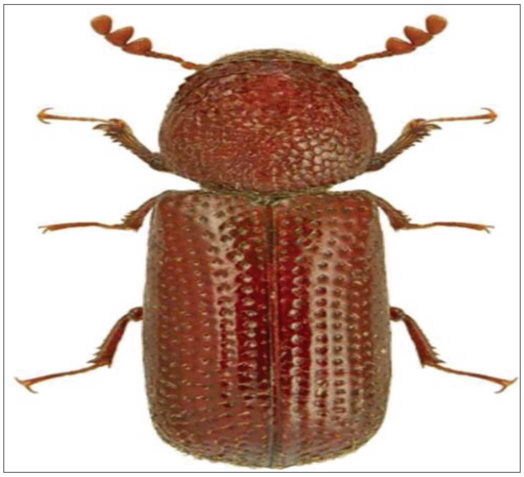

Figure 1: Identification of the insect pest *Rhyzopertha dominica* (Beavis, 1988) [25] of locally processed cereal and legume products in Niger.

3. RESULTS

The storage showed that the identified stock pest was Coleoptera (*R. dominica*) in the broken corn and millet pellet among the processed cereal and legumes studied after 6 months of storage [Figure 1].

Furthermore, only in the ordinary bags, insects were found ranging from 0.66 to 121.33 live insects for broken corn and millet pellet and 0.33–8.33 for dead insects, respectively [Table 1].

There was no infestation observed with the products stored in PICS and sales bags after 6 months of storage that is the second count.

3.1. Physico-functional Parameters

3.1.1. Moisture content

The moisture content of the stored four products [Figure 2] ranged from 2.36% to 8.70%. The products stored in PICS bags showed the lowest moisture content compared to other products after 6 months of storage, among which broken cowpea products have the smallest value followed by the sorghum *degué*.

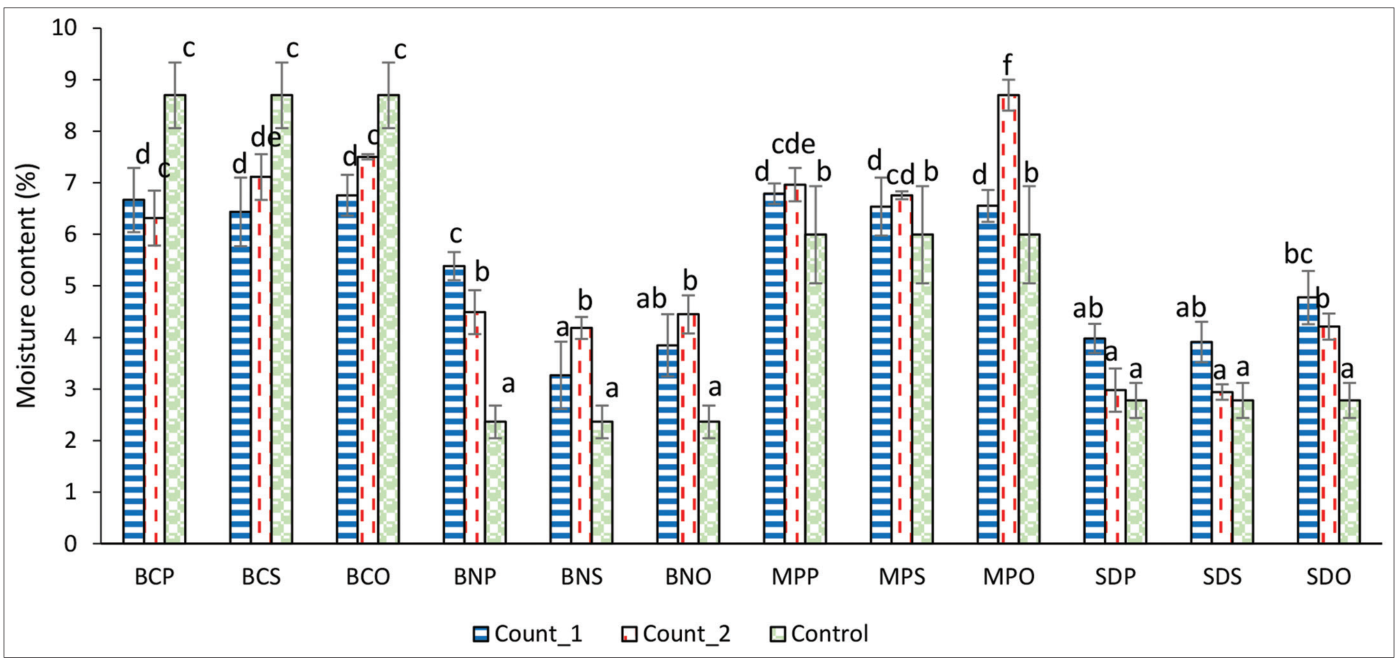

Figure 2: Moisture content of broken corn, broken cowpea, millet pellet, and sorghum *degué*. Values are means ± standard deviation. Charts with the same color (Count_1: $F = 15.396$, $df = 11$, $P = 0.016$; Count_2: $F = 66.259$, $df = 11$, $P = 0.017$; Control: $F = 38.363$, $df = 11$, $P = 0.016$) indicate statistical differences ($P < 0.05$). Samples: BCP: Broken corn kept in PICS bags, BCS: Broken corn kept in sales bags, BCO: Broken corn kept in ordinary bags, BNP: Broken cowpea stored in the PICS bag, BNS: Broken cowpea stored in the sales bag, BNO: Broken cowpea stored in the ordinary bag, MPP: Millet pellet stored in PICS bags, MPS: Millet pellet stored in the sales bag, MPO: Millet pellet kept in the ordinary bag, SDP: Sorghum *degue* kept in the PICS bags, SDS: Sorghum *degue* kept in the sales bag, SDO: Sorghum *degué* kept in the ordinary bag).

Table 1: Average number of insects (live and dead) on the processed cereals and legume products.

Samples	Broken cowpea		Sorghum *degué*		Millet pellet		Broken corn	
Treatments	Live insects	Dead insects	Live insects	Dead insects	Live insects	Dead insects	Live insects	Dead insects
PICS	0	0	0	0	0	0	0	0
Selling bag	0	0	0	0	0	0	0	0
Ordinary bag	0	0	0	0	121.33	8.33	0.66	0.33

PICS: Purdue Improved Cowpea Storage

3.2. pH

A slight increase in the pH values [Table 2] was observed with the breaking corn (5.69–5.96) and that of cowpea (5.19–6.47), then a slight decrease in the pH values for millet pellet (5.87–5.27) and sorghum *degué* (6.03–5.16) for all treatments combined. The pH values of the control products are as follows: Broken corn (6.02), broken cowpea (6.56), millet pellet (3.03), and sorghum *degué* (4.18).

Table 2: pH of broken corn; breaking cowpea; millet pellet; and sorghum *degué*.

Samples	Count_1	Count_2	Control
BCP	5.69±0.16^{d}	5.96±0.04^{c}	6.02±0.12^{c}
BCS	5.38±0.26^{d}	5.71±0.01^{dc}	6.02±0.12^{c}
BCO	5.09±0.36^{d}	5.56±0.07^{c}	6.02±0.12^{c}
BN	5.19±0.18^{c}	6.04±0.04^{b}	6.57±0.02^{a}
BNS	5.23±0.15^{a}	6.23±0.13^{b}	6.57±0.02^{a}
BNO	4.86±0.09^{ab}	6.47±0.09^{b}	6.57±0.02^{a}
MPP	3.16±0.12^{d}	5.74±1.45^{cde}	3.09±0.14^{b}
MPS	5.58±0.04^{d}	4.27±0.02^{cd}	3.09±0.14^{b}
MPO	5.88±0.02^{d}	4.49±0.04^{f}	3.09±0.14^{b}
SDP	6.03±0.02^{ab}	5.02±0.08^{a}	4.18±0.05^{a}
SDS	6.04±0.12^{ab}	5.16±0.06^{a}	4.18±0.05^{a}
SDO	5.73±0.14^{bc}	5.09±0.15^{b}	4.18±0.05^{a}
ANOVA	F=15.396, df=11, P=0.016	F=66.259, df=11, P=0.017	F=38.363, df=11, P=0.016

Samples: BCP: broken corn kept in PICS bags, BCS: broken corn kept in sales bags, BCO: broken corn kept in ordinary bags, BNP: broken cowpea stored in the PICS bag, BNS: broken cowpea stored in the sales bag, BNO: broken cowpea stored in the ordinary bag, MPP: millet pellet stored in PICS bags, MPS: millet pellet stored in the sales bag, MPO: millet pellet kept in the ordinary bag, SDP: sorghum *degué* kept in the PICS bags, SDS: sorghum *degué* kept in the sales bag, SDO: sorghum *degué* kept in the ordinary bag). Values followed by the same letter (a, b, c, d, e, f) are not significantly different ($P<0.05$) by Duncan's multiple range test. Least significant difference (LSD) at 5% level Count_1: $P=0.016$; Count_2: $P=0.017$ and Control: $P=0.016$

3.3. Water-holding capacity and swelling volume

Although the water-holding capacity [Table 3] was higher with the broken cowpea and fluctuated from 1.31 g to 1.42 g and for sorghum *degué* 0.96–1.15 g. Much higher values were found with samples of broken cowpea (1.4 g) and sorghum *degué* (0.94 g). Likewise, the swelling volume [Table 3] revealed higher values with the broken cowpeas (4.03–4.25 g/cm^3) and the sorghum *degué* 3.25–3.76 g/cm^3; than as far the control products, broken cowpea showed to have 4.16 g/cm^3 and sorghum *degué* 3.25 g/cm^3.

3.4. Bulk Density

The results of bulk density at the three treatments showed the broken cowpea (0.71–0.73 g/cm^3), maize breakage (0.68–0.72 g/cm^3), *degué* of Sorghum (0.66–0.69 g/cm^3), and the millet pellet (0.56–0.63 g/cm^3 [Figure3]. The control samples were, respectively, 0.71 g/cm^3, 0.66 g/cm^3, 0.57 g/cm^3, and 0.72 g/cm^3 for broken corn, broken cowpea, millet pellet, and sorghum *degué*.

3.5. Oil Absorption Capacity

The oil absorption capacity obtained with the processed products varied from 1.03 to 1.06 ml/g. The PICS storage bags were 1.04 ml/g to 1.06 ml/g similar to that obtained with the control products which ranged from 1.04 ml/g to 1.05 ml/g [Figure 4].

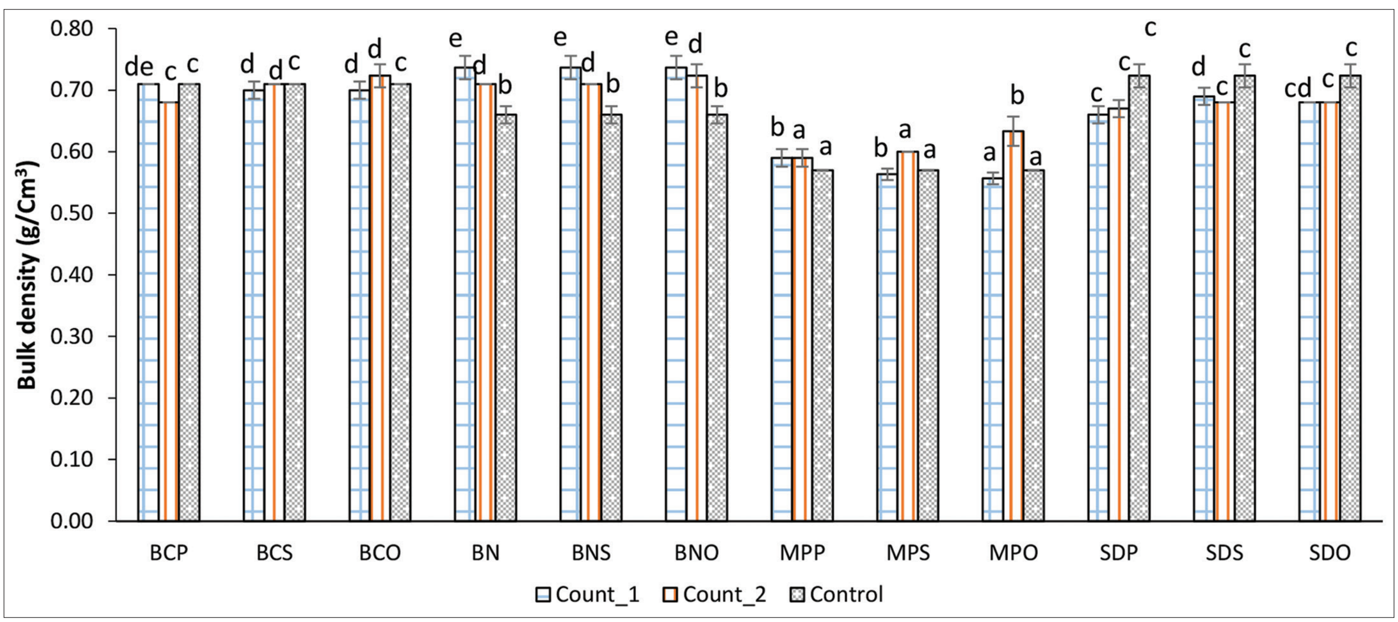

Figure 3: Bulk density of broken corn, broken cowpea, millet pellet, and sorghum *degué*. Values are means ± standard deviation. Charts with the same color (Count_1: $F = 46.585$, $df = 11$, $P = 0.004$; Count_2: $F = 30.142$, $df=11$, $P < 0.001$; Control: NA) indicate statistical differences ($P < 0.05$). Samples: BCP: Broken corn kept in PICS bags, BCS: Broken corn kept in sales bags, BCO: Broken corn kept in ordinary bags, BNP: Broken cowpea stored in the PICS bag, BNS: Broken cowpea stored in the sales bag, BNO: Broken cowpea stored in the ordinary bag, MPP: Millet pellet stored in PICS bags, MPS: Millet pellet stored in the sales bag, MPO: Millet pellet kept in the ordinary bag, SDP: Sorghum *degué* kept in the PICS bags, SDS: sorghum *degué* kept in the sales bag, SDO: Sorghum *degué* kept in the ordinary bag).

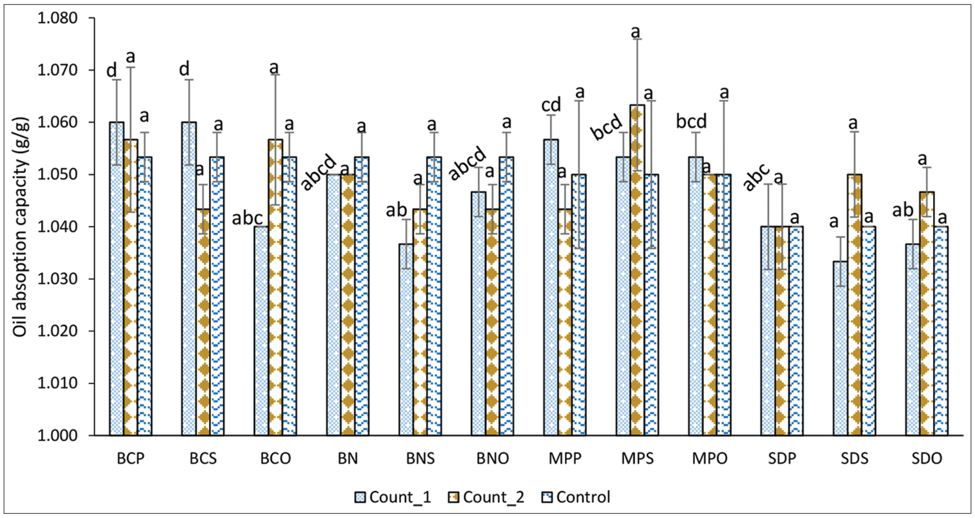

Figure 4: Oil absorption capacity of broken corn, broken cowpea, millet pellet, and sorghum degué. Values are means ± standard deviation. Charts with the same color (Count_1: F=6.250, df=11, $P = 245$; Count_2: F = 0.458, df = 11, $P < 0.001$; Control: F = 1.066, df = 11, $P < 0.001$) indicate statistical differences ($P < 0.01$). Samples: BCP: Broken corn kept in PICS bags, BCS: Broken corn kept in sales bags, BCO: Broken corn kept in ordinary bags, BNP: Broken cowpea stored in the PICS bag, BNS: Broken cowpea stored in the sales bag, BNO: Broken cowpea stored in the ordinary bag, MPP: Millet pellet stored in PICS bags, MPS: Millet pellet stored in the sales bag, MPO: Millet pellet kept in the ordinary bag, SDP: Sorghum degué kept in the PICS bags, SDS: Sorghum degué kept in the sales bag, SDO: Sorghum degué kept in the ordinary bag).

Table 3: Water-holding capacity and swelling volume of breaking corn, breaking cowpea, millet pellet, and sorghum *degué*.

Samples*	Function**	Count_1	Count_2	Control
BCP	WH	2.67±0.24^{a}	2.42±0.12^{a}	1.83±0.12^{a}
	SV	0.70±0.04^{ab}	0.59±0.03^{a}	0.60±0.08^{a}
BCS	WH	2.50±0.35^{a}	2.33±0.24^{a}	1.83±0.12^{a}
	SV	0.74±0.02^{a}	0.64±0.03^{a}	0.60±0.08^{a}
BCO	WH	2.42±0.31^{a}	2.33±0.12^{a}	1.83±0.12^{a}
	SV	0.73±0.03^{a}	0.75±0.01^{a}	0.60±0.08^{a}
BNP	WH	4.12±0.51^{b}	4.03±0.05^{c}	4.17±0.51^{a}
	SV	1.42±0.04^{e}	1.32±0.06^{f}	1.40±0.01^{c}
BNS	WH	4.17±0.31^{b}	3.92±0.12^{c}	4.17±0.51^{a}
	SV	1.39±0.04^{e}	1.40±0.08^{ef}	1.40±0.01^{c}
BNO	WH	4.17±0.24^{b}	4.25±0.20^{c}	4.17±0.51^{a}
	SV	1.42±0.00^{e}	1.33±0.07^{f}	1.40±0.01^{c}
MPP	WH	3.12±0.10^{a}	3.08±0.12^{a}	2.75±0.20^{a}
	SV	0.75±0.10^{bc}	0.62±0.11^{bc}	0.56±0.18^{ab}
MPS	WH	3.23±0.02^{a}	3.08±0.12^{a}	2.75±0.20^{a}
	SV	0.94±0.02^{bcd}	0.74±0.08^{bc}	0.56±0.18^{ab}
MPO	WH	3.50±0.20^{a}	2.83±0.12^{a}	2.75±0.20^{a}
	SV	0.94±0.03^{cd}	0.72±0.04^{b}	0.56±0.18^{ab}
SDP	WH	3.67±0.24^{a}	3.25±0.20^{a}	3.25±0.00^{a}
	SV	1.00±0.01^{cde}	0.97±0.14^{cd}	0.95±0.11^{b}
SDS	WH	3.77±0.21^{a}	3.58±0.31^{ab}	3.25±0.00^{a}
	SV	1.05±0.17^{de}	1.06±0.06^{dc}	0.95±0.11^{b}
SDO	WH	3.42±0.12^{a}	3.33±0.12^{b}	3.25±0.00^{a}
	SV	0.92±0.06^{cd}	1.16±0.04^{cd}	0.95±0.11^{b}
ANOVA	WH	F=23.87, df=11, P<0.001	F=14,2, df=11, P=0.010	F=1.72, df=11, P>0.05
	SV	F=11.04, df=11, P=0.170	F=30.92, df=11, P=0.231	F=14.19, df=11, P<0.01

**Function: WH: Water-holding capacity, SV: Swelling volume; *Samples: BCP: Broken corn kept in PICS bags, BCS: Broken corn kept in sales bags, BCO: Broken corn kept in ordinary bags, BNP: Broken cowpea stored in the PICS bag, BNS: Broken cowpea stored in the sales bag, BNO: Broken cowpea stored in the ordinary bag, MPP: Millet pellet stored in PICS bags, MPS: Millet pellet stored in the sales bag, MPO: Millet pellet kept in the ordinary bag, SDP: Sorghum *degué* kept in the PICS bags, SDS: Sorghum *degué* kept in the sales bag, SDO: Sorghum *degué* kept in the ordinary bag). Values followed by the same letter (a, b, c, d, e, f) are not significantly different (P<0.05) by Duncan's multiple range test. Least significant difference at 5% level

4. DISCUSSION

The constraints faced by the local food processors units, particularly in poor sales, the slow flow of products followed by insect attacks, the main reason behind these could be the poor knowledge of the products by the population and the ineffectiveness of plastic bags used for packaging [26]. Indeed, the research was able to identify *Rhyzopertha dominica* as a damaging insect on broken corn and millet pellet. This pest was already reported in several countries as being one of the most formidable pests causing considerable damage and loss to agricultural products [27]. Indeed, a study in Burkina Faso has shown that *R. dominica* and *Sitophilus oryzea* cause damage to traditional stocks of cowpea and voandzou [28], with similar results on the efficacy of PICS bag rigidity in protecting crops against pest perforation.

Before the use of PICS technology, moisture is always been assessed to ensure the effectiveness of the moisture at which the crop or crop product is stored [13]. The variation in moisture content of the products stored in different types of bags for 6 months in this study has revealed a significant difference with PICS bags that maintain good moisture content during storage due to their airtight effect of it [16,29,30]. Meaningly, the PICS bag as it is impermeable to the exchange between the product and the outside environment as stated by Waongo *et al.* [31].

The pH of a food product can vary from one condition to another, i.e., various factors are responsible for these differences, likewise, this research product showed slight variation in pH values due to the time (6 months) and storage conditions. Similar behavior has been reported by Baik and Donelson [32] for the pH of wheat grains and flour during storage.

The water adsorption capacity decreases with all products stored at the level of the three treatments after 6 months of storage. The water retention capacity obtained with the products stored in PICS bags is similar to those observed with the control products. This could be due to the effect of the PICS bag in preserving the original state of dried food products. However, this result is slightly lower than the one reported by da Silva Timm *et al.* [33] for corn starch. This difference can be explained by the intermediate heat moisture treatment of the corn starch. Indeed, this was also observed in this data on the broken cowpea and sorghum *degué*, much higher when compared to the two other products (broken corn and millet pellet) for all treatments together. Swelling capacity is highly related to water absorption, which implies that lower water absorption is in accordance with low swelling capacity. Remarkably, the swelling volume decreases with all the products stored in the three bags after 6 months of storage. The broken cowpea swells more than the other products, which confirms the statement "Cereal flours swell less than flours from legumes" [24,34,35]. Indeed, this volume is comparable to that obtained from commercial flour reported by Soro *et al.* [6].

The similarity was found with the results of the oil absorption capacity of the products stored in PICS bags and those found in the control samples. The property of oil absorption capacity could be explained due to the fact that the fiber-fiber interactions would expose the hydrophobic surface to adsorb oil [36]; the fact is that the origin of the stored product is with good fiber content. The oil absorption capacity reported is lower than the previous report due to the particle size likely [37] for voandzou (*Vigna subterranea*) flours.

The bulk density differs slightly depending on the particle size of the food product, the smaller the size the larger the bulk density. Indeed, the extent of density, the highest observed with the broken cowpea and that of maize for all treatments combined could be due to the small particle size. The extent of density obtained with these products with the three treatments was comparable to that obtained by Ndouyang *et al.* [38] for the flour of *Tacca leontopetaloides* (L.).

The use of triple-layer plastic (PICS) bags is a simple and low-cost (about US$ 2-3) that brings protection to the small-scale producers from insect damage. It has been reported appreciable economic gain with the use of PICS bags to store grains or other derived products depending on the storage time [29,39]. The small-scale producers in Sub-Saharan Africa work out positively compared to use of standard bags. Factors such as storage time, seasonal price variations, functional and physical properties quality, and product origin affect the net economic. In addition, seasonal price variability and product origin differ a lot among these countries affecting largely the net economy through the end results [29].

5. CONCLUSION

This can be concluded that the problems of storage of processed cereals and legumes product were addressed by the use of PICS bag that shows its effectiveness for preserving the processed products. As a result, the main insect pest found on broken corn and millet pellet was *R. dominica,* and the PICS bags provided protection against this pest with perforation caused by insects after 6 months of storage. The functional and physical properties of the products measured in particular, and the percentage of the water content show significant results with the products stored in the PICS bags. The use of PICS bag for preserving these processed products makes it possible to maintain the organoleptic quality and the physicofunctional properties of the products. Despite that, in some cases, PICS bag and standard types bags did not show significant. Therefore, PICS bag could be a suitable means for storing processed cereals and legumes products.

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7. AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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9. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

10. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

11. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

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