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LABORATORY STUDIES ON THE APPLICATION OF HERMETIC STORAGE FOR PRESERVING ARABICA COFFEE

Glory C. Sabio[*1], Joel V. Dator[1] , Marianne C. Austria[1], and Vicky G. Mesa[2]

[1] Former employees of the Bureau of Postharvest Research and Extension (BPRE), Central Luzon State University (CLSU), Munoz, Nueva Ecija, Philippines
[2] Philippine Center for Postharvest Development and Mechanization (PhilMech) (formerly BPRE), CLSU, Munoz, Nueva Ecija, Philippines
[*]Corresponding author's e-mail*: gcsabio@yahoo.com*

ABSTRACT

Laboratory storage trials of up to 9-month duration were carried out to observe and compare the use of gastight SuperGrainbags (SGB) with plastic woven polypropylene bags (PPB) as storage containers for preserving dried (10-10.8 % m.c.) parchment Arabica coffee. Trials were done under simulated field condition (17.8-21°C; 67.2-85.4% r.h.**)** using incubators, and at ambient room condition (25.7-31.5°C; 59.7-71.8% r.h.). Four (4) replicate bags (10 kg capacity) each filled with approximately 7 kg of dried Arabica coffee were prepared for each kind of storage container and condition for destructive sampling and analyses at predetermined storage periods. Parameters observed were changes in m.c., microbial load, Ochratoxin A contamination, insect infestation, weight loss and sensory attributes (appearance, aroma, flavor and body or mouth feel). Results of the storage trials except the sensory attributes of Arabica coffee are presented and discussed in this paper.

Key words: SuperGrainbags, Polypropylene bags, Arabica coffee, Simulated field condition, Ambient room condition, moisture content, microbial load, Ochratoxin A, insect infestation, weight loss, sensory attributes

INTRODUCTION

Coffee is one of the biggest dollar earner crops grown in the Philippines. The Philippines was the 4th largest coffee exporter in the world before coffee farms were wiped out by the dreaded "coffee rust" disease in 1889 (Albert, 2007). It re-emerged as a coffee exporter again in the 1970's, generating at least US$150 million a year up until 1986. But, the export market started to dry up in the 1990's once more when coffee farming became not profitable because of highly erratic market price, lack of technologies, poor farm to market roads, and lifting of the ban on coffee importation (Asia Pulse News, 2002; Figaro Foundation Corporation, 2006; Albert, 2007). Many farmers sold their coffee farms then or shifted to other crops. However, there was a recent surge in international as well as local demand for coffee beverage. Coffee is being claimed to offer various health benefits and positive functional effects on

concentration, alertness and body endurance among others (Philippine Herbal Medicine, 2006). Cognizant of the promises of a vibrant market to the Philippines' coffee industry, the government and some private organizations started in 2002, to aggressively campaign and tap available resources for the revival of the coffee industry (Asia Pulse News, 2002 ; Asia Pulse News, 2007).

There are four important commercial varieties of coffee grown in the Philippines: Arabica (*Coffea arabica* L.), Robusta (*Coffea canephora* Pierre ex A. Froehner), Liberica (*Coffea liberica* W. Bull. ex Hiern.) and Excelsa (*Coffea excelsa* A. Chev.) (Philippine Herbal Medicine, 2006*)*. Arabica coffee, which accounts for 5-10% of the country's total production (Anenias, 2001) is highly demanded in the market. It is sought by premium coffee buyers worldwide for its elegant and complex flavor. Arabica is twice more expensive than Robusta coffee, therefore increased production of this variety is mainly promoted not only for local consumption but for export as well. Arabica coffee is largely produced in the province of Benguet, Luzon Island, Philippines.

In anticipation of increased coffee production, BPRE explored the development and local application of hermetic storage for coffee at the village level. Coffee farmers and even traders require adequate storage technologies to preserve the qualities of stored coffee and prevent losses especially when prolonged storage becomes inevitable such as when there is a glut in supply and the coffee farmers have to wait for better market price. Prolonged storage of bagged coffee in parchment state and more so as green coffee beans in warm climates under ambient conditions, even when properly dried, could result to gradual loss of beans' taste and aroma, color and density, and mold infection and contamination with toxins and insect infestation (Aronson et al., 2005). The successful use of hermetic storage in preserving the qualities of coffee beans has been reported in Costa Rica (Aronson et. al., 2005) and India and Kenya (Ministry of Agriculture and Rural Development, 2002). The lethal hypoxic atmosphere formed could minimize several oxidative processes that could adversely affect the bean quality and kill microbial and insect pests (Aronson et al., 2005). Furthermore, hermetic storage promotes organic way (no chemical insecticides or pesticides used) of protecting coffee. Many consumers nowadays, local or abroad, are health conscious and are looking for organic products. By choosing organic coffee, small-scale farmers who depend on traditional farming systems are supported and the non-use of hazardous chemical fertilizers and pesticides protects the environment as well. Hence, this study was conducted.

This study aimed at developing an appropriate hermetic storage technology for preserving the qualities and minimizing losses of Arabica coffee during storage and transport at the village level. The specific objectives were to:

a) assess the efficacy of gastight storage containers in maintaining moisture content of coffee, preventing mold growth and toxin contamination, controlling insect infestations, and weight loss in stored coffee, and

b) determine the combined effects of hermetic storage using gastight polyethylene (PE) plastic bags and moisture content on the organoleptic qualities of Arabica coffee

The first objective was investigated under Study l: Laboratory Storage Trial of Arabica Coffee, while objective 2 was observed under Study 2: Sensory Evaluation of Stored Arabica Coffee. The results of Study 1 are presented and discussed in this paper.

MATERIALS AND METHODS

a) Preparation of test coffee:

The required volume of Arabica coffee that was used in the storage experiment was purchased through a middleman from farmers in neighboring farms in Mankayan, Benguet who harvested coffee berries within the first two weeks of December 2009. Procured coffee stock was already depulped and sundried to moisture content ranging from 12-14%. Purchased coffee was transported in gastight containers to BPRE headquarters without delay and sundried further down to 10-12% m.c., rebagged, tempered overnight then used for the experiment on the following day.

Coffee samples for sensory evaluation were gathered from representative samples during the scheduled sampling period then dehulled using a laboratory huller. The resulting green beans were aspirated, packed in 1.2 kg (to come up with 1 kg ground coffee) polyethylene bags then brought to the processor for roasting and grinding. The coffee beans were roasted medium dark at 218°C. The ground coffee samples were brought back to the BPRE laboratory then turned over to the College of Home Science and Industry, CLSU on the following day for sensory evaluation.

b) Storage trial set-up:

Extended storage trials of up to 9-month duration were carried out to observe and compare the use of hermetic or gastight storage containers called SuperGrainbags (SGB) made of transparent multi-layered (with gas barrier between layers), polyethylene plastic (0.078mm) material with plastic woven polypropylene bags (PPB) for storing parchment coffee under two different conditions namely: a) Simulated Field Condition (Benguet) (17.8-21°C; 67.2-85.4% r.h.**)** using incubators, and b) Ambient room condition (Control) (25.7-31.5°C; 59.7-71.8% r.h.).

Four (4) replicates, each one filled with approximately 7 kg of parchment coffee, were prepared for every kind of storage container and condition for destructive sampling and analyses at the end of every predetermined storage period (Table 1).

c) Assessment criteria and frequency of observation:

The effectiveness of the storage containers tested in preserving parchment coffee under the specified storage conditions were based on the parameters listed and sampling schedule shown in Table 2.

All parameters except sensory evaluation were observed and analyzed at the Food Protection Department (FPD) laboratories of BPRE. Moisture contents of coffee were measured immediately after collecting samples using a Dole moisture meter calibrated through oven method. The weight loss that referred to quantity loss or reduction in weight of stored coffee was calculated by weighing the prepared replicate bags of Arabica coffee for observation at pre-determined storage periods (e.g. after 1, 2, 3, 4 to 9 months) and compared these weights with the initial weight of coffee recorded at the start of storage in replicate samples using the formula:

$$\text{Percent weight loss} = \frac{\text{initial weight - weight at end of storage}}{\text{Initial weight}} \times 100$$

Table 1. Coffee storage trial protocol

Storage condition	Storage containers	No. of replicates (7 kg @ rep) per storage/sampling period (months)						Total	
		0	2	3	4	6	9	No. of replicates	Wt (kg)
Simulated Field Condition (Incubators, 18-21°C; 68-85% r.h.)	SGB[a]		4	4	4	4	4	20	160
	PPB[b]		4	4	4	4	4	20	160
Ambient Room Condition (Control, 26-32°C; 58-72% r.h.)	SGB[a]		4	4	4	4	4	20	160
	PPB[b]		4	4	4	4	4	20	160
Total no. of replicates analyzed		4[c]	16	16	16	16	16	84	672

[a]SuperGrainbags
[b]Polypropelene bags
[c]Representative samples randomly collected from stock of test coffee at the start of storage to determine the initial condition for future reference.

Table 2. Test parameters and frequency of observation.

Parameters	Schedule of sampling and analyses (months)
1. Changes in moisture content	0, 2,3,4,6,9
2. Sensory evaluation/organoleptic tests: taste, aroma, color, and body (mouth feel)	0, 2,4,6,9
3. Microbial load	0, 3, 6,9
4. Ochratoxin	0, 3,6,9
5. Insect infestation	0,3,6,9
6. Weight loss	0, 2,3,4,6,9

Microbial infection was determined from thoroughly mixed replicate samples per storage container, condition and duration. Three subsamples of 10 randomly selected coffee seeds each were directly plated in potato dextrose agar for observation. Assays were done starting from 3 up to 7 days after plating. Ochratoxin A contamination in coffee samples was analyzed by the Laboratory Services Division, FPD, using the Immunoaffinity Column (IAC)-Liquid Chromatograph (LC) Method (AOAC). Insect infestation was determined by sieving 500 g sample gathered from each replicate sample. All insects sieved (dead or alive) were then sorted, counted and identified. Representative specimens were properly mounted, and stored.

The temperature and r.h. under the Simulated field and Ambient room conditions were monitored daily throughout the experiment. Monitoring of changes in color of stored coffee, CO_2 and O_2 concentrations inside representative SuperGrainbags was attempted but discontinued because of inadequacy of equipment.

d) Statistical Analyses: Gathered data were subjected to Analysis of Variance (ANOVA) using Split plot in Completely Randomized Design. Statistical significance at 5% level was tested by comparing the F test statistic.

RESULTS AND DISCUSSION

The main species of insect collected from coffee samples stored both in SuperGrainbags (SGB) and in Polypropylene bags (PPB) was the coffee berry borer, *Hypothenemus hampei* (Ferrari 1867). The incidence of *H. hampei* in the Philippines has been reported earlier by Morallo-Rejesus and Baldos (1980). *H. hampei*, a native of Africa, is recognized as one of the most harmful pests of coffee worldwide with Arabica as its preferred host plant (Pest CabWeb 2002; Garcia, 2010). All insects sieved from samples were dead adult insects. Infestation in samples stored in SGB and PPB remained comparable with no significant changes all throughout the storage trial. *H. hampei,* which is considered as field pest, apparently failed to survive the drying process of coffee and probably the storage condition too. The presence of psocids in some samples was occasionally noted however, their occurrence is most likely due to cross infestation.

The moisture content of Arabica coffee stored in SGB and in PPB significantly decreased generally comparably through time (Table 3).

Table 3. Combined effect of storage container and time on m.c. (%) of Arabica coffee.

Container	Storage period (months)			
	0	3	6	9
SGB[a]	10.275a	9.705b	9.275c	8. 48d
PPB[b]	10.375a	9.500bc	8.315d	8.09d

aSuperGrainbags

[b]Polypropelene bags

Note: Values in a row or in a column followed by the same letter are not statistically different at 5% level.

This is despite of the fact that the decrease in m.c. of coffee stored in SGB were more gradual and lesser than those stored in PPB. Storage condition showed no significant effect on the moisture content of coffee stored in SGB under Simulated and Ambient room conditions (Table 4).

The moisture content of coffee stored in PPB under Simulated room condition was similar to those stored in SGB. However, those stored in PBB under Ambient room condition exhibited significantly lower moisture content than those stored under simulated field condition.

Table 4. Combined effect of storage conditions and containers on m.c. (%) of Arabica coffee.

Condition	Containers	
	SGB[c]	PPB[d]
Simulated field condition[a]	9.440a	9.683a
Ambient room condition[b]	9.428a	8.458b

[a] Incubators, 17.8-21°C; 67.2-85.4% r.h.
[b]Control, 25.7-31.5°C; 59.7-71.8% r.h.
[c]SuperGrainbags
[d]Polypropelene bags
Note: Values in a row or in a column followed by the same letter are not statistically different at 5% level.

Decrease in weight loss of Arabica coffee stored in SGB became significant only at 9 month storage while those stored in PPB incurred significant decrease starting at 6 month of storage (Table 5).

Table 5. Combined effect of storage container and time on weight loss from an initial value of 7 kg per bag over time of Arabica coffee.

Container	Storage period (months)			
	0	3	6	9
SGB[a]	7.000a	6.940ab	6.915ab	6.890b
PPB[b]	7.000a	6.900ab	6.715c	6.565d

[a]SuperGrainbags
[b]Polypropelene bags
Note: Values in a row or in a column followed by the same letter(s) are not statistically different at 5% level.

These results indicate that weight loss of coffee resulting from loss of moisture content could be less when kept in SGB. Consequently, the potential monetary gain could be higher when SGB container is used for storing coffee. Furthermore, water absorption and adsorption that could result to fast deterioration of coffee whether during storage or transport may be minimized if not prevented with the use of sealed containers.

Microbial analysis of test coffee stored in both SGB and PPB showed the constant presence of 3 species of fungi, the *Penicillium citrinum*, *Aspergillus niger* and *Aspergillus flavus,* from the onset up to the end of the storage trial both under Simulated field condition and Ambient room condition (Tables 6 and 7).

Table 6. Percentage frequency of isolation of fungi in Arabica coffee stored in PPB[a] and SGB[b] containers under simulated field condition (17.8 -21°C; 67.2-85.4% r.h.).

Fungal species/Storage container	Storage period (months)						
	0	3		6		9	
		PPB	SGB	PPB	SGB	PPB	SGB
Aspergillus niger	3.74	21	19	21	21	21	15
Aspergillus flavus	2.80	8	13	27	40	16	3
Aspergillus oryzae	0	0	0	6	11	3	1
Aspergillus terreus	0	0	0	0	0	3	9
Mucor sp.1	0	11	10	16	12	3	9
Mucor sp.2	0	0	0	8	19	3	10
Mucor sp.3	0	0	0	0	0	3	3
Penicillium citrinum	93.46	99	94	10	3	99	80
Penicillium funiculosum	0	0	0	50	39	0	0
Unknown	0	0	0	0	0	0	0

[a] Polypropelene bags
[b]SuperGrainbags

Table 7. Percentage frequency of isolation of fungi in Arabica coffee stored in PPB[a] and SGB[b] containers under ambient room condition (25.7-31.5°C; 59.7-71.8% r.h.).

Fungal species/Storage container	Storage period (months)						
	0	3		6		9	
		PPB	SGB	PPB	SGB	PPB	SGB
Aspergillus niger	3.74	20	34	34	10	48	31
Aspergillus flavus	2.80	24	31	40	18	14	13
Aspergillus oryzae	0	0	0	7	6	6	4
Aspergillus terreus	0	0	0	0	0	6	3
Mucor sp.1	0	15	13	14	9	12	7
Mucor sp.2	0	0	0	6	5	8	15
Mucor sp.3	0	0	0	0	0	1	0
Penicillium citrinum	93.46	83	95	34	26	29	63
Penicillium funiculosum	0	0	0	0	13	2	2
Unknown	0	0	0	0	0	0	2

[a] Polypropelene bags
[b]SuperGrainbags

Damon (2000) mentioned that some authors reported that due to physical damage caused by *H. hampei*, attacked mature berries become vulnerable to infection and further pest attack. *P. citrinum* was more frequent than the two latter species in the samples but it is not a known Ochratoxin A producing fungus. *A. niger,* on the other hand, has been reported (Abarca et al., 1994; Accensi et al., 2001) as an Ochratoxin producing fungus. Mean percentage infection of coffee samples by this organism did not significantly differ between those stored in SGB and PPB whether under simulated field or ambient room condition up to 3 months (Table 8) but from 6 months onward, those stored in SGB under both conditions, and in PPB under Simulated field condition registered significantly lower infection by *A. niger* compared to those stored in PPB under Ambient room condition. A. *flavus* is associated with *Aflatoxin* production in food. There were other fungal species that were encountered as storage progressed but these are regarded as common storage contaminants.

Table 8. Mean Percentage Infection of *Aspergillus niger* in Arabica coffee beans stored in SGB[a] and PPB[b] containers at different storage conditions.

Storage Condition	Storage Container	Storage Period (months)			
		0	3	6	9
Simulated Field Condition[c]	SGB	4.0	18.5^{BCD}	21.0^{BCD}	15.0^{CD}
	PPB	4.0	21.0^{BCD}	20.8^{BCD}	21.0^{BCD}
Ambient Room Condition[d]	SGB	4.0	34.0^{AB}	10.0^{D}	30.8^{BC}
	PPB	4.0	20.0^{BCD}	34.0^{AB}	47.8^{A}

[a]SuperGrainbags
[b]Polypropelene bags
[c]Simulated field condition, 17.8 -21°C; 67.2- 85.4% r.h.
[d]Ambient room condition, 25.7-31.5°C; 59.7-71.8% r.h.
Note: Values in a row or in a column followed by the same letter (s) are not statistically different at 5% level.

Analysis of test coffee stocks for Ochratoxin A contamination revealed the presence of <0.3 µg/kg (the detection limit of the method used) Ochratoxin A in initial samples (Table 9).

Except in two samples, this level remained in all up to the end of the 9-month storage period. One of the samples kept in SGB under Ambient room condition for 6 month exhibited 0.66 µg/kg Ochratoxin A. The other sample that was stored in PPB under Simulated field condition for 6 months contained 1.1µg/kg Ochratoxin A. Even so, these levels of Ochratoxin A are still far below the safe level of 5µg/kg in roasted coffee beans and ground roasted coffee set by the Commission Regulation (EC) No 1881/2006.

SUMMARY AND CONCLUSIONS

The application of hermetic storage containers using SuperGrainbags (SGB) for preserving dried (10-10.8 %m.c) parchment Arabica coffee was observed and compared with the ordinary plastic woven polypropylene bags (PPB). Laboratory storage trials of up to 9-month duration were conducted under Simulated Field Condition using incubators (17.8-21°C; 67.2-85.4% r.h.), and Ambient Room Condition (25.7-31.5°C; 59.7-71.8% r.h.). The parameters observed were changes in moisture content, microbial load, Ochratoxin A level, insect infestation and weight loss.

Table 9. Levels[a] of Ochratoxin A contamination (ug/kg) in coffee bean samples stored in SGB[b] and PPB[c] under different storage conditions and time.

Storage container	Replicates	Storage time (months)						
		0	3		6		9	
			ARC[d]	SFC[e]	ARC[d]	SFC[e]	ARC[d]	SFC[e]
PPB	R1	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
PPB	R2	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
PPB	R3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
PPB	R4	<0.3	<0.3	<0.3	<0.3	1.1	<0.3	<0.3
SGB	R1	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
SGB	R2	<0.3	<0.3	<0.3	0.66	<0.3	<0.3	<0.3
SGB	R3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
SGB	R4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3

[a]Ochratoxin level of < "value" stands for the detection limit of the method used.
[b]SuperGrainbags
[c]Polypropelene bags
[d]Ambient room condition (25.7-31.5°C; 59.7-71.8% r.h.)
[e]Simulated field condition (17.8 -21°C; 67.2-85.4% r.h.)

Dead adults *Hypothenemus hampei*, was the predominant insect pest collected from Arabica coffee samples stored in SGB or in PPB under Simulated field condition or Ambient room condition. The moisture content of Arabica coffee stored in SGB decreased gradually and lesser than those stored in PPB through time but the changes were significant and generally comparable. Storage condition showed no significant effect on the moisture content of coffee stored in SGB but for coffee stored in PPB, those kept under Ambient room condition exhibited significantly lower moisture content than those stored under Simulated field condition. Significant weight loss in Arabica coffee stored in SGB was only noted at 9 month but those stored in PPB incurred significant weight loss starting from 6 months. *Aspergillus niger*, an Ochratoxin producing fungus, was constantly present in samples kept in SGB and PPB both under Simulated field condition and Ambient room condition from the onset up to the end of the storage trial. However, percentage *A. niger* infection of coffee stored in SGB under both storage condition, and in PPB under Simulated field condition, were significantly lower compared to those stored in PPB under Ambient room condition. Nevertheless, the level of Ochratoxin A in coffee stored both in SGB and PPB under

Simulated and Ambient room conditions generally remained at <0.3 µg/kg up to the end of the 9-month storage period. Only two samples registered increases but the levels were far below the safe level of 5µg/kg in roasted coffee beans and ground roasted coffee set by the Commission Regulation (EC) No 123/2005 as cited in Food and Agriculture Organization of the United Nations (2012).

The effectiveness of hermetic storage using SGB in reducing fluctuations in moisture content and weight loss of coffee was evident. This shows SGB may be used by Arabica coffee farmers, as well as coffee traders and processors in preserving the quality and reducing potential monetary losses too during storage of Arabica coffee, particularly when extended storage becomes inevitable. Present findings likewise provide impetus in pursuing studies that would improve the use of organic or pesticide free hermetic storage not only for preserving the qualities and reducing losses of Arabica coffee but for the other commercially important coffee varieties as well. The inclusion of consumer's preference test in the sensory evaluation of hermetically stored coffee would also be worthwhile.

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