INFLUENCE OF STORAGE CONDITIONS ON QUALITY OF COWPEA SEEDS AND PRODUCTS PROCESSED FROM STORED SEEDS[1]

K.H. MCWATTERS, M.S. CHINNAN,
R.E. WORTHINGTON AND L.R. BEUCHAT

Department of Food Science
University of Georgia Agricultural Experiment Station
Experiment, GA 30212

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ABSTRACT

*Effects of storing cowpeas (*Vigna unguiculata*) at 2°C/65% R.H., 21°C/55% R.H., and 35°C/65% R.H. for 10 months in open metal cans, in high density polyethylene bags flushed with 100% CO_2, and in nylon/saran/curpolymer/polyethylene laminate bags flushed with 100% CO_2 were determined. No major adverse quality changes occurred in cowpeas stored at 2 or 21°C and evaluated as a reconstituted boiled vegetable. Peas stored at 35°C absorbed less water during soaking and required greater force to shear after boiling than peas stored at 2 or 21°C. The rate of death of yeasts and molds on cowpeas stored at 2°C was slower than the rate of death at 21 or 35°C. Decortication efficiency improved under the conditions of storage utilized and may be related to an increase in seed hardness. Cowpeas stored at 2 and 21°C produced akara (fried cowpea paste) with better overall sensory quality than peas stored at 35°C.*

INTRODUCTION

During prolonged storage conditions of high humidity and high temperatures, cowpeas (blackeye peas), like other leguminous seeds, increase in hardness (Sefa-Dedeh *et al.* 1979; Swanson *et al.* 1985). Hardening impairs cookability in that affected seeds do not become tender during cooking, even when the cooking time is greatly extended. When cowpeas are milled into flour or paste, the hard-seed condition could also influence the ease and efficiency of seed coat removal, milling quality, the functionality of milled products, and the quality of foods in which cowpea paste or flour are utilized as a primary ingredient.

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Methods of storage employed in areas of the world which rely upon the cowpea as a major protein-calorie source often do not afford protection for dry seeds, particularly in tropical or subtropical environments. A packaging method which extends the usual shelf-life of peanuts and pecans, both raw and roasted, has been developed by Holaday and coworkers (1979). The method utilizes the CO_2 adsorption properties of these commodities and involves placing them in plastic pouches impervious to air and CO_2, flushing them with CO_2 and then heat-sealing the pouches. CO_2 is adsorbed into the pores of the commodity, forming a vacuum inside the pouch. Likewise, cowpeas packaged by this method also adsorbed CO_2 and produced a vacuum inside the bag. Although no formal quality tests were conducted on the peas, Holaday and coworkers (1979) observed no insect infestation or change in appearance after six months of storage at ambient conditions. Benefits of CO_2 packaging which were noted included its effectiveness, simplicity, low cost, low energy requirements, and adaptability for small or large operations.

The objective of the present study was to determine the effect of storage temperature, package type, and CO_2 on the quality of whole cowpea seeds and meal processed from stored seeds.

MATERIALS AND METHODS

Materials and Storage Conditions

Dry cowpeas were obtained from Hayes Food Products Co., Greenville, SC and held at 2 °C/65% R.H. in paper bags until used. Under these conditions, peas equilibrated at a moisture content of 13%. Prior to packaging for storage, cowpeas were allowed to equilibrate at least 24 h at room temperature and relative humidity. Flexible packaging materials included a high-density polyethylene (Flex-on, Inc., Senoia, GA) and a nylon/saran/curpolymer/polyethylene laminate (Curlon® 550, Curwood, Inc., New London, WI). Permeability properties of these films are shown in Table 1. Peas were divided into 1.8 kg lots, packaged, flushed with 100% CO_2, and sealed with a Multivac AG 500 sealer (Koch, Kansas City, MO). Control samples were stored in metal cans fitted with screen lids. Test and control samples were stored at 2 °C/65% R.H., 21 °C/55% R.H., and 35 °C/65% R.H. Because the controlled environment room at 21 °C was already in use for a long-term storage study, it was not practical to achieve a relative humidity of 65%. In subsequent discussion, environmental conditions involving temperature and relative humidity are referred to as temperature only. After 10 months of storage, samples were removed from storage and evaluated for moisture content, water absorption, sensory quality, texture (shear force), yeast and mold populations, decortication (seed coat removal) efficiency, and quality of akara (deep-fat fried cowpea paste).

Table 1. Permeability properties of the packaging films used for storing cowpeas

Gas or Vapor	High Density Polyethylene[1] (100 micron thick)	Polyethylene Laminate[2] (90 micron thick)
Oxygen ($l/m^2/24$ h)[3]	11.5	< 0.2
Carbon dioxide ($l/m^2/24$ h)[3]	36.0	< 1.0
Water vapor ($g/m^2/24$ h)[4]	18.4	0.077

[1]Sacharow and Griffin 1980
[2]Technical Service Bulletin, Curwood, Inc., New London, WI
[3]At 25 °C, 0% R.H., 1 atm
[4]At 37.8 °C, 90% R.H., 1 atm

Analysis of Whole Seeds and Meal

Moisture content of whole seeds was determined by drying 5 g samples in a forced-air oven at 103 °C for 72 h (AACC 1983). Moisture content of cowpea meal processed from stored seeds was determined by vacuum drying 5 g samples for 24 h at 70 °C. Water absorption was determined by soaking peas in excess tap water for 15 h at 25 °C, after which peas were blotted dry and weighed. Peas to be evaluated for sensory quality and objective texture measurements were soaked overnight (40 g peas in 300 mL of tap water) and boiled for 40 min in the soak water to which sufficient salt had been added to give a final salt concentration of 1%. Samples were evaluated for sensory attributes of appearance, color, aroma, texture, and flavor by seven experienced panelists. Evaluations were conducted in partitioned booths under incandescent lighting. Each sample was evaluated in duplicate, with duplicate evaluations conducted on different days. A scale of 9 to 1 was used for scoring, with 9 representing the highest score for each attribute. Objective texture measurements of 25 g samples were made with a Food Technology Corp. texture-test system equipped with a standard shear-compression cell and 136 kg transducer ring. Peak heights were measured and converted to Newtons/gram (N/g) of cooked sample.

Duplicate samples (20 g) were analyzed after 5 and 10 months storage for total yeast and mold populations. Cowpeas were deposited in 80 mL of 0.1 M potassium phosphate buffer (pH 7.0) and homogenized in a Colworth Stomacher for 2 min. The wash buffer was serially diluted and surface-plated (0.1 mL) in duplicate on plate count agar supplemented with 50 μg/mL each of chlortetracycline-HCl and chloramphenicol. Colonies were counted after 3-5 days incubation at 25 °C.

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Decortication

A mini-PRL dehuller developed at the Plant Biotechnology Institute of the National Research Council, Saskatoon, Canada (Reichert *et al.* 1984) was used in decorticating the cowpea samples. Cowpeas from two 1.8 kg lots stored under similar conditions were combined from which 3.2 kg batches were used for decortication. Decortication was done in six one-minute stages. At the end of each stage, the dehuller was stopped and the grain was removed. The fines were separated by passing through a No. 20 Tyler sieve. The hulls, eyes and other light material were aspirated using a seed cleaner. The cleaned material was weighed to determine the percent extraction level or percent kernel removed. A 100 g sample was saved to estimate decortication efficiency parameters, and the remainder was reintroduced into the dehuller for the next stage of decortication. The 100 g samples mentioned above were classified into several categories for estimating decortication efficiencies as described by Hudda (1983).

Analysis of Cowpea Paste and Akara

Akara is a deep-fat fried food which contains cowpea paste as the principal ingredient. It was utilized to evaluate functionality and end product quality that may have been affected by storage. Paste was prepared from decorticated whole seeds and from meal processed from stored, then decorticated seeds. Procedures for preparing meal and paste and frying conditions have been described by McWatters and Brantley (1982) and McWatters (1983). Physical measurements of apparent viscosity of whipped paste and shear force, moisture content, and crude fat content of akara were determined by procedures described previously (McWatters 1983; McWatters and Chhinnan 1985).

Sensory quality attributes of akara were evaluated by an experienced ten-member panel using four-point scales for sponginess (4 = very spongy, 1 = slightly spongy), oiliness (4 = very oily, 1 = slightly oily), aroma and flavor (4 = typical of akara, 1 = severely off or objectionable), and preference (4 = like extremely, 1 = dislike). A set of three to four samples consisting of an unidentified control (sample stored at 2 °C in open metal can) and coded products from the various storage temperature/packaging treatments was evaluated at each session. Samples for each set were prepared in the morning, cooled to room temperature, and covered with aluminum foil until evaluated at mid-afternoon. Samples were arranged in random order on heat-resistant white plates, reheated at 205 °C for 4 min in a conventional oven, and evaluated while warm in individual booths equipped with incandescent lighting. Tap water at room temperature was provided for the panelists to rinse their mouths after tasting each sample.

Statistical Analysis

Data were analyzed using analysis of variance procedure, PROC ANOVA, of Statistical Analysis System-SAS 79 (Helwig and Council 1979).

RESULTS AND DISCUSSION

The permeability properties of the flexible packaging materials (Table 1) were considered in their selection. The laminated film has the capability of maintaining introduced atmospheres and is an effective moisture barrier. While polyethylene does not prevent interchange with atmospheric gases, it is economical, has effective moisture barrier properties, and could possibly retain CO_2 for sufficient time to permit CO_2 fumigation to control infestation by the cowpea bruchid, *Callosobruchus maculatus*. Although both types of flexible packages were flushed with CO_2, only the laminated film retained the CO_2 atmosphere during storage. No insect infestation was detected in any of the packages after 10 months of storage.

Storage temperature and packaging interaction had a significant effect on the moisture content, water absorption, shear force, and yeast/mold populations of cowpeas (Table 2). As was to be expected, moisture content was affected to a greater extent when cowpeas were stored in open cans than in closed flexible bags. For example, the highest (13.1%) and lowest (9.4%) moisture concentrations were observed in samples stored in open cans. There was little difference in the moisture barrier properties of the two flexible films when compared within temperatures except at 35 °C where moisture concentration was higher in cowpeas packaged in high-density polyethylene than in laminated film. Samples stored at 35 °C in either of the flexible packages absorbed less water during soaking than any of the other treatments. Shear force values of cooked peas indicate that increasing the storage temperature increased the hardness of cowpeas packaged in both types of flexible film. For cowpeas stored in open cans, there was no difference in the force required to shear samples at 2 or 21 °C. Cowpeas stored in open cans at 35 °C were significantly harder than similarly packaged samples at 2 or 21 °C but were not as hard as samples packaged in flexible film and stored at 35 °C.

Stanley and Aguilera (1985) and Aguilera and Stanley (1985) recently reviewed the textural defects in cooked reconstituted legumes. They concluded that there are several mechanisms, none being completely dominant, which are responsible for seed hardening and postulated that these mechanisms may have a nonenzymatic as well as enzymatic component. Hardening defects are initiated by structural and compositional factors but can be controlled, at least partially, by storage and processing conditions.

Table 2. Effect of storage temperature and package type on moisture content, water absorption, shear force, and yeast/mold populations of cowpeas[1]

Storage temperature (°C)	Package type[2]	Moisture (%)	Water absorption (%)	Shear force (N/g)	Yeast/Mold Population (per g) 5 months	Yeast/Mold Population (per g) 10 months
2	C	13.1[a]	106.1[ab]	6.2[ef]	395[c]	325[b]
	H	12.5[bc]	106.9[ab]	5.2[g]	1162[a]	662[a]
	L	12.7[ab]	106.5[ab]	5.5[fg]	682[b]	747[a]
21	C	9.4[g]	109.4[a]	6.0[ef]	98[d]	45[c]
	H	12.4[bc]	105.0[ab]	6.5[e]	108[d]	12[c]
	L	12.2[c]	104.3[b]	7.4[d]	53[d]	10[c]
35	C	10.5[f]	102.9[b]	12.9[c]	13[d]	0[c]
	H	11.6[d]	93.2[c]	18.8[a]	3[d]	5[c]
	L	11.1[e]	96.2[c]	15.3[b]	0[d]	0[c]

[1]Values in a column not having a common superscript are significantly different at $P \leq 0.05$. Unless otherwise indicated, data were taken after 10 months storage.

[2]C = control samples stored in open metal cans, H = samples stored in high-density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

The rate of death of yeasts and molds on cowpeas stored at 2 °C was slower than the rate of death at 21 or 35 °C. After 5 and 10 months, populations were significantly higher in all samples stored at 2 °C. Storage under temperature and relative humidity conditions evaluated in this study would protect cowpeas against fungal deterioration.

For sensory data analysis of whole seeds and akara, control sample scores corresponding to each set were analyzed to test their variation among sets. No statistical difference at the 5% significance level was found among controls. This allowed the sensory data for control samples to be pooled and analyzed, as the objective data were, as a function of storage temperature and package type.

Analysis of sensory data revealed that appearance, color, and aroma scores of soaked, boiled cowpeas were not significantly influenced by the conditions of storage. Flavor scores were significantly influenced by storage temperature but not by package type. Peas stored at 2 and 21 °C received the same mean flavor score (7.5) which was significantly higher than the mean flavor score (6.5) for peas stored at 35 °C. Panelists frequently described the flavor of samples stored at 35 °C as "undercooked" and "weak;" off-flavor was rarely mentioned as a reason for the lower score of the 35 °C samples.

Storage temperature and package type had major effects on texture scores (Table 3). Mean scores for peas stored at 2 and 21 °C were not significantly different from each other but were significantly higher than the mean score for peas stored at 35 °C. Samples stored in polyethylene and laminate bags had similar mean scores for texture which were significantly lower than the mean score for peas stored in open cans. Panelists frequently described samples which received low texture scores as "hard" and "undercooked." The sensory evaluations for texture coupled with the objective data for water absorption and texture (shear force values) indicate that the flexible package/CO_2 atmosphere treatment did not prevent but rather enhanced the development of a hardened condition in cowpeas stored at high temperature and high humidity.

Table 3. Sensory evaluation of the texture of cowpeas cooked after 10 months of storage[1]

Storage temperature (°C)	Package Type			
	Open can	Polyethylene bag	Laminate bag	Mean
2	7.4	7.2	7.4	7.3[a]
21	7.4	7.4	7.2	7.3[a]
35	5.7	4.4	4.8	5.2[b]
Mean	6.9[a]	6.3[b]	6.5[b]	

[1]Means values in a column or row not having a common superscript are significantly different at $P \leq 0.05$

A recent study by Onayemi *et al.* (1986) has shown that storing cowpeas in a nitrogen atmosphere effectively maintained the good quality attributes of cowpeas, including nutritional and water imbibition properties. Nitrogen storage was more effective than metal drums or jute bags for maintaining seeds with good cookability characteristics and was recommended for use in the major cowpea producing regions of Africa as a means of reducing food loss and preventing the misuse of chemical preservation methods.

Hudda (1983) defined various parameters describing decortication efficiency such as PEL (percent extraction level or percent of usable material recovered), PWOE (percent of decorticated cowpeas with the hilum completely removed), and PUD (percent of completely undecorticated cowpeas). Estimates of PWOE and PUD at 90% extraction level (PEL) for various storage conditions are given in Table 4. Improvement in decortication efficiency is seen from the increase in PWOE values and reduction in PUD values. Generally, PWOE values increased with the increase in storage period and storage temperature. However, storage period had a more pronounced affect than storage temperature. Although no general pattern was observed in PUD values, PUD values of cowpeas stored at 35 °C were estimated to be lower after 10 months of storage compared to those after 5 months of storage. Increase in hardness of the cotyledons in storage is believed to contribute to the improvement in decortication efficiency.

In evaluating the effects of storage of cowpea seeds on akara quality, it was necessary to adjust the moisture in paste made from either whole seeds or meal to a uniform content before frying. Moisture content of whole seeds and meal and the quantity of water required for these adjustments are shown in Table 5. Final moisture content before frying of paste from whole seeds and meal was 61.3% and 60.0%, respectively. For whole seeds, pastes made from 2 °C samples required the least additional water whereas the 35 °C samples, having decreased water absorption capacity, required the most additional water.

The effect of temperature for storing cowpeas on some physical characteristics and sensory scores of akara made from meal and whole seeds are shown in Table 6. For akara prepared from meal, greater force was required to shear samples made from peas stored at 35 °C than at 2 and 21 °C. This may have been due to the hardening phenomenon associated with high-temperature/high moisture storage, to the significantly lower crude fat content of the 35 °C products, or to both factors. Preference scores for akara prepared from either meal or whole seeds and aroma-flavor scores of akara made from whole seeds were significantly lower when cowpeas were stored at 35 °C than at 2 or 21 °C. Panelists rated the flavor of akara from the 2 and 21 °C treatments as "reasonably typical of akara" whereas akara from the 35 °C treatment was rated as "slightly off." For preference scores, panelists indicated that they "liked moderately" akara made from the 2 and 21 °C treatments whereas akara from the 35 ° treatment was "liked slightly." Other sensory attributes, i.e., sponginess and oiliness, were not influenced significantly by storage temperature or type of packaging.

Table 4. Decortication efficiency of cowpeas at 90% extraction level for selected storage conditions

Storage temperature (°C)	Package type[1]	Percent of seeds with hilum completely removed (PWOE) Duration of Storage, months 5	10	Percent of completely undecorticated seeds (PUD) Duration of Storage, months 5	10
2	C	77.1	82.5	9.3	10.9
	H	73.2	78.1	11.4	12.2
	L	65.5	81.3	19.1	8.5
35	C	76.0	83.4	15.8	7.7
	H	76.2	85.4	13.8	9.2
	L	75.7	86.8	11.5	10.3

[1]C = control samples stored in open metal cans, H = samples stored in high-density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

Table 5. Moisture content of whole cowpea seeds after 10 months of storage and of meal processed from stored seeds and the quantity of water added to adjust cowpea pastes to the same moisture content before frying

Storage temperature (°C)	Package type[1]	Whole Seeds: Moisture Content (%) Initial	Whole Seeds: Moisture Content (%) Soaked peas	Whole Seeds: Wt. soaked, dehulled peas (g)	Whole Seeds: Water added (ml)[2]	Meal: Moisture content (%)	Meal: Water added (ml)[3]
2	C	13.1	33.8	248.88	167	11.0	245
	H	12.5	33.4	249.87	168	10.9	246
	L	12.7	33.8	250.39	166	10.5	248
21	C	9.4	30.2	246.69	188	9.8	251
	H	12.4	32.3	245.78	176	10.9	246
	L	12.2	33.2	249.76	169	11.0	245
35	C	10.5	29.1	240.02	194	10.2	249
	H	11.6	30.0	239.93	189	10.6	247
	L	11.1	30.3	242.42	186	10.6	247

[1]C = control samples stored in open metal cans, H = samples stored in high density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

[2]Amount of water added to 232 g of soaked, dehulled peas was calculated such that the final moisture content of the paste was 61.3%.

[3]Amount of water added to 200 g of meal such that the final moisture content of the paste was 60.0%.

Table 6. Effect of temperature for storing cowpeas on some physical characteristics and sensory scores of akara prepared from meal and whole seeds[1]

Storage temperature (°C)	Meal			Whole Seeds	
	Shear force (N/g)	Crude fat[2] (%)	Preference score	Aroma-flavor score	Preference score
2	9.42^{b}	23.77^{a}	2.9^{a}	3.1^{a}	3.0^{a}
21	9.31^{b}	24.74^{a}	3.1^{a}	3.1^{a}	2.9^{a}
35	10.42^{a}	21.13^{b}	2.3^{b}	2.6^{b}	2.5^{b}

[1]Values in a column not having a common superscript are significantly different at $P \leq 0.05$. Cowpeas were stored for 10 months, and meal was processed from stored seeds.
[2]Dry weight basis.

The interaction of storage temperature and type of packaging had a significant effect on the viscosity of paste made from either meal or whole seeds and on several characteristics of akara (Table 7). Paste made from hydrated meal had lower and more variable viscosity values overall than paste made from whole seeds. This may have been due to disruption of the usual pathways and mechanisms of water imbibition for intact seeds (Sefa-Dedeh and Stanley 1979) which were altered by milling rather than to differences in method and time of hydration for preparing paste from whole seeds and meal (McWatters and Chhinnan 1985). The lowest viscosity values were noted in meal-based paste from the 35 °C storage treatment. Aroma-flavor scores of meal-based akara were higher when the peas from which the meal was made were stored at 2 or 21 °C than at 35 °, regardless of the type of packaging. For akara prepared from whole seeds, relationships between storage conditions and shear force values, moisture content, and crude fat content were not readily apparent because the data were variable and unordered. This variation was especially evident in the moisture and fat content data at 35 °C where the highest and lowest values were observed.

Table 7. Effect of cowpea storage conditions on viscosity of cowpea paste and some characteristics of akara[1]

Storage temperature (°C)	Package type[2]	Meal: Paste Apparent viscosity[3] (Pa.s)	Meal: Akara Aroma-flavor score	Whole Seeds: Paste Apparent viscosity (Pa.s)	Whole Seeds: Akara Shear force (N/g)	Whole Seeds: Akara Moisture (%)	Whole Seeds: Akara Crude fat[4] (%)
2	C	21.7^{a}	3.1^{ab}	37.6^{a}	13.27^{bc}	43.1^{bc}	36.5^{ab}
	H	20.3^{ab}	3.0^{ab}	35.5^{b}	12.56^{bcd}	44.9^{ab}	35.1^{abc}
	L	19.5^{b}	3.0^{ab}	35.6^{b}	12.69^{bcd}	45.1^{ab}	34.6^{a-d}
21	C	16.5^{c}	3.3^{ab}	35.2^{b}	11.39^{d}	46.2^{a}	33.0^{cd}
	H	20.6^{ab}	3.4^{a}	36.5^{ab}	13.79^{ab}	42.7^{bc}	35.5^{abc}
	L	20.9^{ab}	3.0^{ab}	36.3^{ab}	11.89^{cd}	45.3^{ab}	34.9^{a-d}
35	C	15.3^{cd}	2.5^{dc}	36.6^{ab}	13.20^{bc}	47.4^{a}	31.8^{d}
	H	14.8^{d}	2.1^{d}	35.0^{b}	15.15^{a}	41.9^{c}	37.6^{a}
	L	15.4^{cd}	2.8^{bc}	35.0^{b}	13.86^{ab}	44.8^{ab}	34.1^{bcd}

[1]Values in a column not having a common superscript are significantly different at $P \leq 0.05$. Cowpeas were stored for 10 months, and meal was processed from stored seeds.

[2]C = control samples stored in open metal cans, H = samples stored in high density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

[3]Brookfield Viscometer Model RVT. Model C Helipath stand, T-B spindle, 5 rpm; dial readings × conversion factor of 0.8 = values in Pa.s.

[4]Dry weight basis.

CONCLUSIONS

Storage at 2 and 21 °C was effective in maintaining the quality of cowpeas for use as a reconstituted, boiled vegetable and as akara (fried cowpea paste), regardless of packaging treatment. The flexible packaging/CO_2 atmosphere treatment did not prevent but actually enhanced the development of a hardened condition in cowpeas stored under conditions of high temperature and high humidity. Cowpeas would be protected from fungal deterioration under the storage conditions utilized in this study. The improvement in decortication efficiency which occurred may have been due to an increase in seed hardness. While practical, effective approaches are of immediate need to prevent quality losses in legumes during conditions of adverse storage, an even greater need exists to elucidate the underlying mechanisms responsible for seed hardening.

This study has reconfirmed that high temperature and high humidity storage conditions should be avoided if the quality of cowpea seeds is to be maintained. If cowpeas are to be used as flour, milling prior to development of a hardened condition may minimize the undesirable textural changes that occur when whole seeds are stored under adverse conditions.

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