FUNCTIONAL AND END-USE PROPERTIES OF VARIOUS COMMODITIES STORED IN A LOW OXYGEN ATMOSPHERE

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ABSTRACT

Germination, milling, and breadmaking characteristics of wheat were unaffected by exposure to a generated or combustion atmosphere composed of less than 1% oxygen, 9.0-9.5% carbon dioxide and the balance principally nitrogen for periods of 1/2 to 6 months. Similarly, germination, milling and cooking properties of long- and medium-grain rice exposed as rough, brown and milled rice were unchanged after 6-months of treatment. No adverse effect on the quality of malt produced from barley stored in the atmosphere was observed and no significant reduction was obtained in the germination of the barley. Almonds and raisins stored in the low oxygen atmosphere were equal or superior in flavor, quality, and acceptability to samples stored in normal atmospheres for periods as long as one year.

INTRODUCTION

In U.S. agriculture, modified atmospheres of various compositions have been used to prevent the spoilage of foods and to create storage environments where it is possible to maintain the keeping qualities and growth characteristics of several types of fruits, feeds, vegetables and ornamental plants. Examples are the controlled atmosphere (CA) storage of apples to retain marketable conditions; the storage of animal feeds to maintain vitamin content and palatability; and the "blanketing" of food products such as macaroni, pickles, dried milk and citrus products during processing and transportation. Nitrogen and carbon dioxide are listed in the U.S. Federal Register under Title 21 - Food and Drugs as multiple purpose food substances generally recognized as safe when used under good manufacturing practices. The combustion gas produced by exothermic inert atmosphere generators has also been recognized by the U.S. Federal Food and Drug Administration as a secondary direct food additive when used to displace O_2 in the processing, storage or packaging of beverage products and other foods (CRF, Title 21, Chapter 1, Part 173.350).

Previous studies with low oxygen atmospheres produced by exothermic inert atmosphere generators emphasized their use as a direct residue-free substitute for conventional chemical fumigation of grain. Equally important is their potential use in providing a modified storage environment for the continuous protection of bulk stored grain and other agricultural products.

Studies were developed to document the effects of long term storage in the generated "combustion" atmosphere on quality of grain, grain products and other bulk stored food commodities. Data presented here were obtained from the following sources: Storey et al., 1977; Guadagni et al., 1978a and 1978b; Storey and B. Webb, USDA Regional Rice Quality Laboratory, Beaumont, Texas (unpublished data; and Storey and K. Finney, USDA Grain Quality and End-Use Properties Unit, U.S. Grain Marketing Research Laboratory (unpublished data).

MATERIALS AND METHODS

Controlled atmosphere generator

A laboratory scale exothermic modified atmosphere generator built by Gas Atmospheres, Inc. of Port Washington, WI was used in the tests. The generator produces 2.83 M^3/hr of modified atmosphere composed of less than 1% O_2, 9-9.5% CO_2, 86-89% N_2, 1% Ar, and 1.5% or less each of H_2 and CO. Oxygen levels in the modified atmosphere were measured periodically throughout each test period with a paramagnetic oxygen analyzer. Although some minor variations occurred during day-to-day operations, the concentrations of O_2 in the modified atmosphere flowing through the various commodities was within a range of 0.25 - 0.5%.

Commodity treatments

(Cereal Grains)

Hard red winter wheat, two types of rice (long grain-Lebonnet and medium grain - Brazos) in the form of rough, brown, and milled rice and two malting barley cultivars (six-rowed type-Larker and two-rowed type-Klages) were subdivided into lots of 55 kg (wheat), 2,000 g (rice) and 1,000 g (barley) that were either placed in plastic containers 28 cm x 28 cm x 90 cm (wheat) or 1.9 liter glass jars (rice and barley) and stored under a flowing (50 to 100 cc/min) generated atmosphere or in a normal atmosphere. Wheat was treated at a temperature of 27 $\pm$ 1°C and 50 $\pm$ 5% relative humidity. Rice and barley were treated at temperatures of 18 $\pm$ 1 or 20.5 $\pm$ 1 and 27 $\pm$ 1°C and 50 $\pm$ 5% relative humidity. Treatment periods were 1/2, 1, 2, 3, and 6 months for wheat and 1, 3, and 6 months for rice and barley. A control sample of each commodity was held in a sealed container stored at 4°C during the test period. Samples removed from generated atmosphere or normal air storage during the test period were held at 4°C until processed and analyzed.

(Commercial Malts)

Two commercial malts (brewer's and distiller's) were stored in lots of 425 g in 0.95 liter glass jars under generated or normal atmospheres at 15 $\pm$ 5% and 65 $\pm$ 5% relative humidity and 27 $\pm$ 1°C. Samples were removed after storage for 3, 6, and 12 months and held with control samples at 4°C until analyzed.

(Almonds)

Nonpareil inshell almonds and almond meats were subdivided into 2,000 gram lots and stored in 3.8 and 1.9 liter glass jars under a flowing (50 cc/min) generated or normal atmosphere at 50 ± 5% relative humidity and 18 ± 1 and 27 ± 1°C. Sample lots were removed after storage for 1, 3, 6, 9, and 12 months.

Nonpareil inshell almonds were also subdivided into 223 kg lots and stored in metal silos (45 cm in diameter by 4.27 m high) under flowing (500 cc/min) generated atmosphere, flowing normal air, and static air. Samples (33 kg) for quality evaluation were drawn from the silos after storage for 1, 3, 6, 9, and 12 months. Untreated samples and samples removed from the jars and the silos during the test period were held at 4°C until analyzed for flavor stability.

(Raisins)

Field run Thompson variety raisins were subdivided into 1362 gram lots and stored in 1.9 liter glass jars under flowing (50 cc/min) generated or normal atmosphere and static air at 50 ± 5% relative humidity and 18.5 ± 1 and 27 ± 1°C. Sample lots from each treatment were removed after storage periods of 1, 3, 6, 9, and 12 months. Untreated raisins and raisins removed from the jars during the test period were held at 4°C until submitted for flavor sensory evaluation.

Analytical methods

(Wheat)

Milling, flour analysis, and breadmaking characteristics of the treated wheat were determined by the Grain Quality and End-Use Properties Unit of the U.S. Grain Marketing Research Laboratory. Germination tests were conducted by the Kansas Board of Agriculture, State Seed Laboratory. Ash and protein were determined as described by American Association of Cereal Chemists (1962). The baking procedures of Shogren et al (1969) for 10 g flour samples were used in the breadmaking studies.

(Rice)

Tests to measure the effect of storage of the rice in the generated atmosphere were conducted by the USDA Regional Rice Quality Laboratory, Beaumont, Texas. Physiocochemical Properties generally recognized as tests of cooking quality, including amylograph peak and setback viscosities, alkali spreading values, and water uptake values were determined for each rice sample. Milling yields of rough and brown rice and germination of rough rice were also determined. Tests for parboil-canning stability were used to evaluate the suitability of the treated rice for use in heat processed foods such as soup (Webb and Adair 1970).

(Barley and Commercial Malt)

The barleys were malted as described by Dickson et al. (1968) and the malts were analyzed by the USDA Barley and Malt Laboratory, Madison, Wisconsin according to the methods of the American Society of Brewing chemists (1958).

(Almonds and Raisins)

All sensory evaluations of flavor stability of the treated almonds and raisins were performed by laboratory personnel of the USDA Western Regional Research Center, Berkeley, California. The shelled almonds and raisins were placed in coded paper cups and presented to a panel of judges for ranking in order of least off-flavor. Separate tests were also conducted to determine the relative likeability or acceptability of the samples from different treatments (ASTM, 1968).

RESULTS

Cereal Grains

Storage for 1/2 to six months at temperatures ranging from 18 ± 1 to 27 ± 1°C, a relative humidity of 50%, and flowing atmospheres containing less than 1% oxygen that were produced by the exothermic inert atmosphere generator had no consistent or significant adverse or beneficial effect on the functional and end-use properties of dry stored wheat, rice or barley. Presentation of data is therefore simplified by giving only the results for the longest exposure period (6 months) at the highest temperature (27 ± 1°C).

Germination of each grain stored in the generated atmosphere was consistent with the viability of grains stored in normal air at the same temperature or under cold storage (4°C) Table 1).

TABLE 1.

Germination of wheat, rice, and barley stored for 6-months at 27 ± 1°C and 50 ± 5% relative humidity in normal air or in atmospheres produced by an exothermic inert atmosphere generator (composition <1.0% O_2, and 9.0-9.5% CO_2, the balance principally N_2) or at low temperature in normal air.

Commodity	Generated atmosphere	Normal air	Cold Storage (4°C)
Wheat (HRW)[1/]	90	91	93
Rough rice (long grain)	90	91	92
Rough rice (medium grain)	92	91	93
Barley (six-rowed)	95	96	95
Barley (two-rowed)	98	98	97

1/ HRW = hard red winter wheat

Milling characteristics, flour analysis and breadmaking properties of wheat stored in the generated atmosphere were virtually identical to those of wheat stored in normal air or cold storage (Table 2). The reduction in loaf volume was somewhat less for bread made from wheat held in cold storage than from wheat stored in the generated atmosphere or normal air.

TABLE 2.

Milling characteristics, flour analysis, and bread making properties of wheat stored for 6 months at 27 ± 1°C and 50% relative humidity in normal air or in atmospheres produced by an exothermic inert atmosphere generator (composition <1.0% O_2, and 9.0-9.5% CO_2, the balance principally N_2) or at low temperatures in normal air.

Factor	Cold storage (4°C)	Generated atmosphere	Normal air
Milling characteristics1/			
Ash (%)	1.66	1.65	1.65
Protein (%)	11.3	11.0	11.0
Flour yield (%)	74.8	74.1	73.9
Chemical analysis of flour1/			
Ash (%)	0.43	0.40	0.40
Protein (%)	10.3	9.9	10.1
Characteristics of bread2/			
Mixing time3/ (min)	3 5/8	3 1/2	3 1/2
Baking absorption (%)	65.9	67.5	66.8
Loaf volume4/	816	805	806

1/ Chemical data expressed on a 14% moisture basis.
2/ Crumb grains and crumb colors were satisfactory for all treatments.
3/ Corrected to 12.0% protein.
4/ Corrected to 10.0% protein.

Milling yields, amylographic viscosity and physiochemical (quality) characteristics of long grain and medium grain rice varieties stored as rough rice, brown rice and milled rice in the low oxygen generated atmosphere were also consistent with results obtained from rice stored in normal air or cold storage. Table 3 shows data obtained for rice milled after storage for 6 months as rough rice.

The storage of six-rowed and two-rowed barley under the generated atmosphere had no significant effects on the quality of malt produced from the stored barleys (Table 4). Some slight improvement in increased diastatic power and alpha-amylase occurred in the two-rowed barley stored in air compared to barley stored in the generated atmosphere, but these changes are not considered to be of practical importance.

Commercial malts

There were no significant changes in any of the malts stored for three months at 15 or 65% R.H. nor in malts stored for 6 or 12 months at 15% relative humidity. Malts stored for 6 and 12 months at 65% relative humidity had increased moisture content to such an extent that the final moisture level probably had a greater effect on malting characteristics than the composition of the air under which they were stored. Significant decreases in extract, wort protein, diastatic power and alpha-amylase and increases in fine - coarse grind extract and wort color occurred in each malt stored at high relative humidity. Under these conditions, storage in the generated atmosphere did not provide any advantage or disadvantage over storage under normal air.

TABLE 3.

Milling yields, amylographic viscosity, and physicochemical (quality) characteristics of long grain (Lebonnet) and medium grain (Brazos) rice varieties stored as rough rice for 6 months at 27° ± 1°C and 50% R.H. in normal air or in atmosphere produced by an exothermic inert atmosphere generator (composition <1.0% O_2, and 9.0-9.5% CO_2, the balance principally N_2) or at low temperatures in normal air.

Factor	Long Grain Rice			Medium Grain Rice		
	Cold Storage (4°C)	Gen. atms.	Air	Cold Storage (4°C)	Gen. atms.	Air
Test weight 1 bushel	45.6	45.4	45.3	46.2	46.5	46.4
Milling yield whole kernel %	66.4	65.8	66.2	66.1	66.3	66.2
Amylographic viscosity						
Peak B.U.	740	760	785	690	663	670
After 10 min at 95°C B.U.1/	415	465	470	355	345	345
Breakdown B.U.1/	325	295	315	335	320	325
Milled rice analysis						
Alkali spread value 2% KOH	4.4	4.3	4.8	6.9	6.8	6.9
Swelling No. at 77°C	80	79	76	203	190	223
Swelling No. at 95°C	508	492	478	523	513	495
Amylose content %	24.9	24.9	24.3	18.3	18.4	18.6
Brown rice protein %	7.56	7.57	7.33	8.11	8.17	7.89
Parboil-canning stability						
Solids loss	16.1	16.2	14.6	26.1	26.0	25.9

1/ Barbender Units

TABLE 4.

Composition and malting characteristics of two malting barley varieties stored for 6 months at 27 ± 1°C and 50% relative humidity in normal air or in atmospheres produced by an exothermic inert atmosphere generator (composition <1.0% O_2, and 9.0-9.5% CO_2, the balance principally N_2) or at low temperatures in normal air.

Factor	6-rowed barley LARKER			2-rowed barley KLAGES		
	Cold Storage 4°C	Gen. atms.	Air	Cold Storage 4°C	Gen. atms.	Air
Moisture	12.2	12.2	11.9	11.9	12.0	11.7
Fine grind extract (%)	78.1	78.3	78.9	80.4	80.3	80.7
Fine coarse graind extract (%)	1.9	1.7	1.7	1.7	2.1	1.9
Wort color (SRM)[a]	1.9	1.9	1.9	1.2	1.2	1.3
Malt-protein (%)	13.44	13.56	13.25	13.50	13.69	13.69
Wort-protein (%)	5.19	5.20	5.42	4.87	4.81	4.97
Wort/malt protein (%)	39.1	39.5	41.4	37.0	36.6	38.1
Diastatic power (°L)	188	190	187	160	161	166
Alpha-amylase (20°C)	42.7	40.9	41.8	51.3	56.4	58.7

[a]Standard reference method.

Almonds

Sensory comparisons of flavor changes indicated that storage in the low oxygen generated atmosphere caused less off-flavor development that storage in normal atmosphere for both nut meats and inshell almonds. Higher storage temperature increased off-flavor development in meats stored in normal air, but had no significant effect on those stored in the generated atmosphere.

Raisins

Raisins stored under the low oxygen generated atmosphere for up to 1 year were equal or superior in flavor quality and acceptability to similar samples stored under flowing or static normal air.

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