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Effect of Storage Time, Moisture Level and Headspace Oxygen on the Quality of Dehydrated Egg Mix

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SUMMARY

A full factorial study was conducted to determine the effect of storage time, moisture, and available oxygen on the flavor, odor, and texture of spray-dried scrambled egg mix stored at a high temperature. Analysis of variance indicates that storage time, available oxygen, and moisture levels contribute significantly to the deterioration of the color and flavor of dehydrated egg mix. The deteriorative effect of moisture and storage time on texture are significant, but the effect of available oxygen is not significant. Estimation of the components of variance indicates that, although significant for color and flavor, the variance attributable to oxygen is small in comparison to the amount attributable to moisture. Color appears to be the attribute affected first at lower levels.

INTRODUCTION

Spray-dried whole egg is an item of commerce that is used in several areas of food processing and has been used extensively in military feeding. The effects of moisture level, composition of the headspace gas, and storage temperature on the shelf life of the product have been reported by a number of investigators.

Most investigators found a relationship between moisture and storage temperature. Hawthorne (1943) used changes in the flavor of the product to determine the extent of deterioration and found a reduction of 36 to 75% from the initial scores, depending upon the moisture level, when the eggs were stored at 98.6°F. White et al. (1943a) found the rate of deterioration increases with increased moisture levels at all temperatures studied between 55°F and 110°F as measured by fluorescence, solubility in KCl and refractometric values.

Thistle et al. (1944) found deterioration in dry eggs containing 1.4% moisture after 30 and 15 days at 99°F and 118°F respectively. Other investigators (Boggs et al., 1946; Pearce et al., 1946; and Stewart et al., 1943) found that low moisture levels increased the shelf life of the product. White et al. (1943b) determined deterioration of quality was rapid at 75°F and above and recommended storage temperatures of 60°F or lower to maintain quality.

White et al. (1943b) found that packaging egg powder with nitrogen or in a vacuum did not improve the shelf life of the product but that carbon dioxide had a definite preservative effect. Bate-Smith et al. (1943) found no retardation of deterioration when nitrogen was used. Boggs et al. (1946) noted a slight improvement in keeping quality when the egg powder was packed with nitrogen but reported a four-fold increase in keeping quality when carbon dioxide was used.

Thistle et al. (1944) found carbon dioxide had a beneficial effect, but Pearce et al. (1946) found only slightly greater improvement in keeping quality when eggs were packed in carbon dioxide as compared with air or nitrogen. Kline et al. (1953) found no advantage of nitrogen gas containing 20% carbon dioxide over 100% nitrogen gas in stabilizing acidified and glucose-free egg powders.

Attempts have been made to improve the shelf life of spray-dried whole eggs by acidification of the egg pulp (Boggs et al., 1946; Pearce et al., 1946), by the addition of edible food grade chemicals (Brooks et al., 1943; Pearce et al., 1944; Kline et al., 1964a; Kline et al., 1964b) and by removal of the natural sugar from the egg (Hawthorne et al., 1944).

Kline et al. (1953) stored acidified and glucose-free egg powders and found the organoleptic stability of the glucose-free powder to be superior to the acidified powder under all conditions of storage. Kline et al. (1954) studied the quality and stability of whole egg powder desugared by the yeast fermentation and enzyme methods. They found equivalent stability in egg powders desugared by the two methods when the pH was the same in the egg melange prior to drying. Enzyme desugared powder was slightly grainy when made into scrambled eggs.

The research cited above was conducted with spray-dried whole eggs. In general, the results reported are not considered applicable to the spray-dried scrambled egg mix. The majority of the experiments reported above were not conducted over a period sufficiently long and under sufficiently adverse conditions to apply to the conditions often encountered in the military supply line. Few organoleptic evaluations were reported.

In general, the Armed Services have not been satisfied with the quality of spray-dried whole eggs which they have used for years. In the early 1960's, the Army-Air Force Master Menu Board examined a commercial scrambled egg mix and found it to be, in their opinion, superior to the whole egg mix. At their request, the U.S. Army Natick Laboratories tested the new product and found that it had better storage stability than the whole egg mix and recommended adoption by the Services. Since that time large quantities of the egg mix have been procured and reports from the field have been very favorable.

Suppliers of the product to the Department of Defense have questioned the necessity of the 2.0% moisture and oxygen levels in the specification. Logic dictates that if one or both of these factors could be made less restrictive, the cost of the product could be reduced. Therefore, a research study was initiated to evaluate the effect of moisture and available oxygen on the stability of spray-dried scrambled egg mix stored at 100°F.

EXPERIMENTAL

Preparation of the dehydrated egg mix. A slurry of egg mixture of the composition: fresh whole egg, 64.6%; condensed skimmed milk, 30%; corn oil, 4.8%; and sodium chloride, 0.6% was prepared. The slurry was heated to 130°F, homogenized at 2000 psi, and pasteurized at 145°F for 3.5 min. The pasteurized egg mix was cooled to 125°F and spray-dried in a Nerco-Niro Laboratory Spray-Drier using an air inlet temperature of 365°F and an air outlet temperature of 194°F. The dry powder was sealed under vacuum in 603 × 700 size cans and held at 40°F until prepared for storage.

The powder was weighed and placed in a twin-shell blender. Moisture was adjusted to 2.0, 2.5, 3.0, 3.5, or 4.0% as required by spraying a calculated amount of water over the surface of the powder then allowing the egg powder to mix until the moisture was equilibrated throughout the product. The moisture level was determined by running samples of the powder on

Table 1. Oxygen uptake for 30 g of scrambled egg mix and average panel ratings when the product is stored at 100°F with different levels of vacuum and moisture.

		Vacuum (Inches)[1] 30					20					0				
		Moisture (Percent)														
Time (Weeks)		2.0	2.5	3.0	3.5	4.0	2.0	2.5	3.0	3.5	4.0	2.0	2.5	3.0	3.5	4.0
	O_2 Used (ml)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	Flavor Rating	6.0	6.2	6.4	6.3	5.9	6.0	6.2	6.4	6.3	5.9	6.0	6.2	6.4	6.3	5.9
	Color Rating	6.8	6.8	7.0	6.8	6.7	6.8	6.8	7.0	6.8	6.7	6.8	6.8	7.0	6.8	6.7
	O_2 Used (ml)	1	1	1	1	1	1	3	1	4	3	7	8	10	12	12
3	Flavor Rating	6.0	6.4	6.0	5.5	5.6	5.8	5.4	6.4	5.9	5.1	6.1	5.8	6.0	5.1	5.7
	Color Rating	6.4	6.5	6.4	6.3	5.9	6.6	6.8	6.9	6.2	6.1	6.7	6.8	7.0	6.5	6.1
	O_2 Used (ml)	2	2	2	1	2	4	5	2	7	8	4	4	5	12	12
6	Flavor Rating	6.2	5.8	6.6	5.3	5.3	6.1	6.6	5.5	5.1	5.2	6.2	6.2	6.1	3.9	5.1
	Color Rating	6.7	6.9	6.4	5.3	4.1	6.6	7.0	6.4	5.7	4.8	6.8	7.0	6.6	5.2	6.2
	O_2 Used (ml)	2	1	2	2	1	6	6	6	11	11	16	15	16	27	27
12	Flavor Rating	5.6	5.6	5.0	3.4	4.5	6.1	6.6	5.0	4.0	3.7	5.7	5.5	4.9	3.1	4.0
	Color Rating	6.3	6.2	5.8	3.1	2.6	6.2	6.7	6.0	3.4	2.2	6.2	6.5	6.1	3.1	4.1
	O_2 Used (ml)	1	2	2	2	2	9	8	11	11	11	22	21	24	34	34
24	Flavor Rating	5.5	5.5	4.8	3.2	2.3	4,5	5.3	4.0	2.2	2.6	4.2	5.0	4.4	3.0	2.5
	Color Rating	4.8	5.9	4.4	1.9	1.7	5.6	6.1	4.6	2.3	1.7	5.5	6.2	5.6	2.3	1.7

[1] Oxygen available to the 30 g of product at these vacuums was 2 ml at 30 in., 12 ml at 20 in. and 36 ml at 0 in.

the Cenco moisture balance.

After adjusting the moisture to each level a portion was removed and five aliquots of 30 g each were canned in 300 × 200 cans under 30 or 20 in. of vacuum or atmospheric pressure which corresponds approximately to 1, 7 and 21% of oxygen, respectively, in a gas-packed product. The product was placed at 100°F and samples were withdrawn after 0, 3, 6, 12 and 24 weeks of storage.

Headspace gas was analyzed using the chromatographic method of Bishov et al. (1966). Prior to analysis the cans were brought to atmospheric pressure with nitrogen and allowed to equilibrate over night.

Organoleptic quality was evaluated by a ten member technological panel. The samples at each withdrawal were served in random order, and three samples were examined at each panel session. Color, odor, flavor, and texture were evaluated using a 9-point scale where the highest number on the scale indicated the most acceptable product characteristic. The eggs were prepared for evaluation by reconstituting the powder on the basis of 33 g of powder and 90 ml of water in a glass beaker. The beaker was placed in gently boiling water and the eggs stirred until cooked to the consistency of scrambled eggs.

Total headspace volume in the can was determined by compressing the contents (30 g) of a can at 2000 psi for 10 sec and subtracting the volume of the bar thus formed (30.7 cc) from the volume of the can (200 cc). The total headspace volume was used in calculating the uptake of oxygen by the product during storage.

Table 2. Analysis of variance.

Source of Variance	Color	Odor	Flavor	Texture
Moisture	**	**	**	**
Available oxygen	**	*	*	n.s.
Storage time	**	**	**	**
Moisture × available oxygen	**	n.s.	n.s.	n.s.
Moisture × storage	**	**	**	**
Available oxygen × storage	**	n.s.	n.s.	**
3 factor interaction	**	**	**	**

* $p > 0.05$ ** $p > 0.01$ n.s. — not significant

Table 3. Components of variance.

Source of Variation	Percentage of Variation: Color	Odor	Flavor	Texture
Moisture	17.1	9.3	4.3	7.4
Available oxygen	2.6	1.7	2	3.2
Storage time	26.5	32.1	28.5	16
2 factor interaction	18.5	8.4	6.7	13.3
3 factor interaction	29.4	11.7	20.2	11.2
Not accounted for	5.9	36.8	38.3	48.9

RESULTS AND DISCUSSION

Table 1 shows the average panel ratings for flavor and color and the oxygen uptake by 30 g of the product when stored at 100°F. Color seems to be the controlling organoleptic attribute since it goes off at a faster rate than flavor. The panel ratings are those from a trained technological panel and should not be compared to the results obtained from a consumer panel. Generally, in-house consumer panels give higher ratings to this product than does the technological panel, particularly initial ratings.

Table 2 shows the analysis of variance results. Effects of all variables and interactions on color were significant at the 1% level. While the effects of moisture on color, odor, flavor, and texture were significant, the effect of oxygen was not significant on texture nor was the effect of the moisture × oxygen interaction significant on odor, flavor, and texture.

The data were analyzed by the method of Hicks (1956) to show the distribution of the variance (Table 3). The storage time at 100°F accounted for approximately one-third of the total variance for each of the organoleptic factors studied except texture. Available oxygen, however, accounted for very little of the variance.

The color of the scrambled eggs deteriorated to varying degrees during the storage time, depending upon the moisture level. At higher moisture levels (3.5 and 4.0%) the color, after 24 weeks of storage, was yellowish-brown, similar to the color of cooked, canned pumpkin. Deterioration of the color at these moisture levels was noted at the 6 and 3 week withdrawals for 3.5 and 4.0% moisture, respectively. Browning was evident in the product containing 2.0 and 2.5% moisture only after 24 weeks storage, but browning was noted in the 3.0% moisture samples at the 12 week withdrawal.

Available oxygen was not as important in the deterioration of color as were moisture and storage time. In fact, the average panel score was higher in many instances in samples with 7 or 21% available oxygen in the headspace gas than in samples under vacuum.

Flavor did not deteriorate as rapidly as color. If the eggs had been judged solely on the basis of color, samples with 3.5 and 4.0% moisture would likely have been judged to be unacceptable after 12 and 6 weeks of storage, respectively. Peryam et al. (1952) point out that most foods fall into the range of 5.5 to 7.5 on a 9-point acceptance scale, and that foods falling below 5.0 on the scale are generally of poor quality. They caution, however, not to regard the scale as absolute.

Although moisture was important in the deterioration of flavor, oxygen in the headspace played only a minor role. During the 24 weeks of storage the samples containing 2.0, 2.5, and 3.0% moisture deteriorated an average of 1.7 points, whereas, samples containing 3.5 and 4.0% moisture deteriorated an average of 3.3 points in flavor.

The data indicate that texture is more difficult for a panel to judge than color or flavor. Oldfield (1960) discusses the enormous complexity of the perception of texture. He points out that the physiological and psychological mechanisms of the individual and the mechanical properties of the food are all interrelated. Tuomy et al. (1968) also observed that the panel had difficulty evaluating the texture of beef and chicken stews. They did not advance an explanation for the difficulty.

Table 2 shows that the amount of oxygen in the headspace is not a significant factor affecting the texture. Table 3 shows that the results for texture are not as distinct as for color, odor and flavor. Almost one-half of the variance for texture was not accounted for by variables studied or their interactions.

The data for oxygen absorption (Table 1) show that in samples with low oxygen levels the total amount of oxygen available was absorbed in 3 to 6 weeks regardless of the moisture level. At the intermediate and high concentrations of oxygen in the headspace gas the percentage of oxygen absorbed was related to the moisture level. Samples containing 2.0% moisture and 12 and 36 ml of available oxygen initially, had absorbed 75 and 61%, respectively, of the oxygen by the end of storage (24 weeks). Samples of 4.0% moisture and the same initial levels of available oxygen (12 and 36 ml) had absorbed 92 and 94% of the oxygen at the end of 24 weeks.

Results of this study confirm the validity of the specification requirement for a moisture level not exceeding 2.0%. It might be argued from the data that a maximum of 2.5% could be allowed. However, considering first that raising the moisture level generally decreases the storage life and second, that a cushion is necessary for proper administration of a specification in procurement, 2.0% is the logical maximum.

Although oxygen plays a much less important role in deterioration, it does have a significant effect and must be considered. Storage at 100°F was an important cause of deterioration and informal in-house studies have shown that lower storage temperatures will extend the storage life of the egg mix substantially. Although the product used in these studies was prepared under laboratory conditions, it is believed that the results can be applied to product prepared commercially since they parallel results of informal in-house storage studies of commercial products.

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