2025

EFFECTS ON PRODUCT QUALITY OF CROSS-CIRCULATION AIR DRYING OF WHOLE MILK FOAM

Cross-circulation drying of whole milk foam was studied at the Engineering and Development Laboratory of the Eastern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, as part of a broad program directed toward the development of a commercially feasible process for preparing beverage-quality dry whole milk of rapid dispersibility and adequate shelf life. A beverage quality product is one possessing flavor similar to flash-pasteurized fluid milk and is free of the characteristic cooked flavor of present dry milks. Techniques for drying whole milk foam under vacuum and some properties of this product have been reported (1, 4, 5, 9). The spray drying of whole milk foam is also under study in this program (6). In addition, cross-circulation drying of whole milk foam was begun at the Eastern Division in 1959 after Morgan et al. (8) of the Western Division had devised a new method which they called foam-mat drying. In the course of their work with a wide variety of foodstuffs, they prepared dry whole milk of good dispersibility. Their method involved addition of a stabilizing agent to milk concentrates, preparation of a foam by incorporating air or an inert gas, application of this foam to a tray or a moving belt and exposing it to a hot air stream until dry. Since good dispersibility was one of the important goals of our work, a special dryer was built at the Eastern Division and a continuous unit was set up to study the mechanism of drying and to provide information needed to adapt drying conditions and techniques to obtain the best product quality. The purpose of this paper is to report the effects of drying conditions on the quality of the resulting product.

EXPERIMENTAL PROCEDURES

Figure 1 is a flow sheet of the pilot plant used in these studies. Concentrate of 40 to 46% solids made from whole milk flash-pasteurized at 162 F for 16½ sec was chilled to below 50 F. Nitrogen was then dispersed in the concentrate by means of a gas-liquid mixer to yield a foam of 0.4 g/cc density. It was found that a stabilizer was not required for the preparation of suitable foams. The foam was applied in the form of ropes to the belt of a continuous, cross-circulation air dryer. Rope diameters ranged from 0.05- to 0.10-in. Air conditions studied were: velocity from 240 to 710 ft/min, dry-bulb temperature from 112 to 232 F, and relative humidity from 1 to 24%.

Product quality was measured by the Solubility Index Test of the American Dry Milk Institute (3), and by an organoleptic scoring test similar to the one adopted by the American Dairy Science Association (2). The taste panel consisted of 8 to 11 trained judges. The final flavor score reported for each sample was the panel's arithmetic average score for that sample.

RESULTS

Drying. A comprehensive report on the engineering aspects of the drying study may be found elsewhere, along with supporting experimental evidence (7). Findings pertinent to this report are: (a) Drying time between two given moisture contents varied as the square of the rope diameter. (b) Foam temperature during drying was an important variable affecting drying rate. (c) Relative humidity had no effect on drying rate, but only on the final moisture content that could be attained. (d) Air velocity had a slight effect on drying rate which could be explained on the basis of its effect on foam temperature.

Flavor. Products prepared using a wide range of drying temperatures and drying times were presented to a trained taste panel for flavor evaluation. In all cases these products were found to be unsatisfactory, due to the development of an oxidized off-flavor (Table 1), although results indicate some improvement in flavor with decrease in drying time.

TABLE 1

Flavor evaluations

Total drying time	Dry-bulb air temp	Avg score of fresh whole milk standard	Avg score of sample	Most objectionable flavor
(min)	*(F)*			
6.0	143	38.8	28.5	Oxidized
5.1	121	39.5	28.1	Oxidized
4.6	174	39.5	30.0	Oxidized
3.4	174	39.5	32.0	Oxidized
3.2	209	39.5	35.5	Oxidized
1.8	209	39.3	34.4	Oxidized
1.3	209	39.3	35.7	Oxidized
1.1	209	39.3	35.1	Oxidized
1.0	232	39.0	31.5	Oxidized
0.92	232	39.0	32.3	Oxidized

Heat damage. The ADMI Solubility Index Test was used as a measure of the heat damage to the product. Experiments were made to determine the effect of dry-bulb temperature and drying time on the solubility index. Results are given in Table 2. They show that the dry-bulb temperature must be restricted to meet the standards of solubility index, that this temperature limit is about 232 F with ropes of 0.05-in. diameter, and that it is lower with thicker ropes.

TABLE 2
Heat damage due to drying

Dry-bulb air temp	Rope diameter	Drying time	Moisture	Solubility index
(F)	*(in.)*	*(min)*	*(%)*	*(ml)*
174	0.05	2.1	3.47	Trace
174	0.075	3.0	3.53	Trace
174	0.10	6.3	2.82	Trace
209	0.048	1.8	3.13	0.1
209	0.048	1.3	3.36	Trace
209	0.05	2.2	2.47	0.3
209	0.075	3.2	3.52	0.6
209	0.10	5.47	3.73	0.4
209	0.10	3.3	4.55	1.0
232	0.048	1.0	3.05	0.4
232	0.048	0.92	3.57	0.5

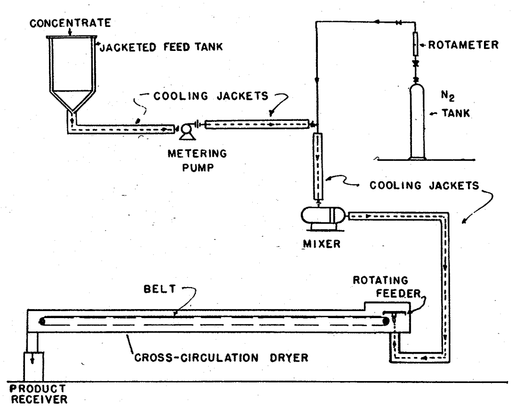

FIG. 1. Flow sheet of the pilot plant used to study the cross-circulation air drying of whole milk foams.

DISCUSSION

The main limitation in applying this process to whole milk is the development of an oxidized off-flavor. Results of this work show that less oxidized off-flavor is developed as drying time is decreased by employing higher dry-bulb temperatures. However, dry-bulb temperature has an upper limit because of heat damage, as evidenced by solubility index. Even when drying at the upper limit, sufficient oxidative defect is developed to render the product unsatisfactory when dried in air.

It is common practice when drying food products to lower the dry-bulb temperature as drying proceeds to reduce heat-induced deteriorative reactions. In this case, the chief problem was the development of an oxidized off-flavor shown to increase as the dry-bulb temperature was lowered (drying time increased). Thus, temperature lowering as drying proceeds did not offer a solution to the oxidation problem.

There are other means that may be considered for overcoming oxidative deterioration during processing of milk. Heat-treating the fluid milk prior to spray drying is commonly employed to inhibit fat oxidation. However, this treatment imparts a decided cooked flavor to the product, inconsistent with the objectives of this work. Moreover, other work (5) has shown that heat treatment impairs dispersibility of the dry milk on storage. Drying in an inert gas atmosphere would inhibit oxidative deterioration, but would add substantially to the cost and complexity of the operation.

Although drying time can be decreased by the use of rope diameters smaller than the 0.05-in. used in this work, it would be difficult to approach the short time of exposure to oxidation possible in spray drying. Spray drying is cheap and, with the recent development of spray drying of foamed concentrates (6), improved dispersibilities can be had. Moreover, dry whole milk of excellent initial flavor and dispersibility can be made by the continuous vacuum drying of foamed concentrates (1). Through pilot-plant research the cost of the vacuum process is now approximating profitability. Work on cross-circulation drying has been discontinued, as it offers little prospect of yielding a product of the desired properties at a reasonable cost.

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