Effect of Pollution of Air with Ozone on Flavor of Spray-Dried Milks

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Abstract

In an investigation of seasonal variations in the flavor quality of milk powders manufactured in the Dairy Products Laboratory, we conducted a series of experiments in which low-heat, spray-dried milks were manufactured during a period of low background levels of ozone. The effect of ozone on the flavor of dried milks was ascertained by manufacturing, in each experiment, powders both with and without addition of ozone to the dryer air, and subsequently evaluating their flavor by a trained taste panel.

Levels of ozone reported by others as occurring in the atmosphere of the Washington area during the warm weather months were sufficient to lower substantially the flavor score of dried milks. Skimmilk powders manufactured in air containing 32 ppb (parts per billion) ozone averaged 1.7 flavor points (on a ten-point scale) lower than those manufactured under a background level of 2 ppb. Under the same conditions, whole milk powders averaged 2.9 points lower than the control powders. Foaming heightened the damaging effect of ozone on flavor quality. Raising the ozone level from 32 to 52 ppb produced little or no further effect on the flavor of whole milk powder and only a questionable effect on the flavor of skimmilk powder.

For years we have noted a seasonal variation in the flavor quality of our experimental milk powders. Those manufactured during cold-weather months have been consistently good; whereas, those manufactured during hot-weather months have been variable in quality. During this season the incidence of poor-quality powders has been frequent enough to be a serious bar to manufacture of dried whole milk with a flavor equal to that of fresh milk.

In a systematic study of this problem we eliminated bacterial contamination and ordinary air oxidation from having any significant seasonal effect on our dried milks. We then focused our attention on air pollution. We found that the condensate formed by passing high-purity cylinder air through liquid nitrogen–cooled traps, when combined with milk, did not affect its flavor. In contrast, the condensate from plant air during the off-flavor season gave an off flavor to milk. The character of this off flavor, however, differed from that associated with the low-score milk powder.

Of the known air pollutants, ozone has a number of qualities from which one might connect it with our off-flavor problem. Ozone in the air has large seasonal variations, being relatively low in the winter and high in the summer. Moreover, during the summer its levels fluctuate widely. It is well known that ozone is highly reactive with many organic compounds. Naturally occurring levels can produce injury to growing plants (4, 5). To our knowledge, it has not been reported that naturally occurring levels of ozone can damage the flavor of a food product.

We describe a series of experiments in which spray-dried milk was manufactured during a period of low background levels of ozone. The effect of ozone on the flavor of dried milks was ascertained by manufactcring, in each experiment, powders both with and without addition of ozone to the dryer air, and subsequently evaluating their flavor by a trained taste panel.

Experimental Procedures

Foam and conventionally spray-dried milks were prepared from low-heat pasteurized milk (15 sec at 77 C) as previously described (1, 3). The foamed powders were obtained by addition of 57 liters per minute of nitrogen to 4.1 kg per minute of 45% solids whole milk concentrate or to 3.6 kg per minute of 40% solids skimmilk concentrate.

Ozone was added to the dryer air by passing oxygen from a cylinder successively through a flowmeter, a silent discharge ozone generator, and Teflon tubing into the spray dryer at a point between the air intake and the blower (Fig. 1). With a rated air blower capacity of

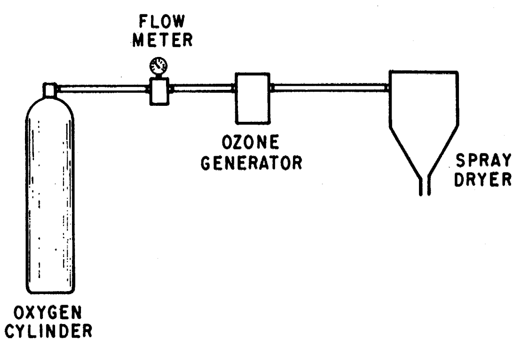

FIG. 1. Introduction of ozone into spray dryer.

about 2×10^5 liters per minute, we found that oxygen flow rates of 300-500 ml per minute gave the desired ozone concentrations.

The air sample was taken for analysis at a point between the blower and the heater (Fig. 2). At this sampling point, air in the dryer is under pressure. The excess pressure was relieved by diverting part of the air sample through a T-tube into the atmosphere. By manipulating the pinch clamp at this point while observing the pressure changes in the open-end manometer, the air sample could be brought to atmospheric pressure at the entrance to the Mast Ozone Meter sampling tube. In this meter, ozone reacts with iodide ions. A resultant electric current is measured on a modified recorder with a full-scale deflection equivalent to 100 ppb (parts per billion) ozone. A chromium trioxide scrubber, when included in the air sampling line as shown, removes sulfur dioxide from the air sample (7).

During each experiment, four types of powder were made in a continuous operation from the same milk concentrate. The powders were collected in the following sequence: A, a foamed, ozonized powder; B, a nonfoamed, ozonized powder; C, a foamed, nonozonized powder; D, a nonfoamed, nonozonized powder. Between the collection of each sample, sufficient powder was discarded to clear the dryer of the preceding powder.

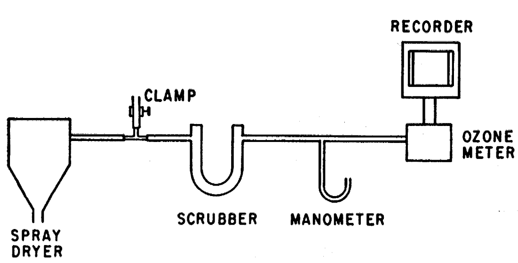

FIG. 2. Apparatus for sampling and measuring ozone concentration in dryer air.

These powders were reconstituted, refrigerated overnight, and evaluated by a ten-man trained taste panel, using a scoring system previously described (6).

Results

A seasonal variation in the flavor quality of dried milks is shown by the data in Fig. 3. The height of each bar represents the loss in flavor score from converting milk concentrate to milk powder. The data were averaged for each month during one calendar year, for 56 experiments.

Table 1 shows the effect of ozone level on the flavor score of dried milk. At the average ozone level of 2 ppb during these experiments, the control powders scored about one-half point below their concentrates. At an ozone level of 32 ppb, the powder flavor deteriorated sharply. The still higher ozone level of 52 ppb had little or no further effect on the powder flavor. Whole milk powder was more susceptible than skimmilk powder to the damaging effects of ozone.

Fig. 4 shows that the larger surface areas produced by foaming the powder (2) is associated with a greater loss of flavor score. This enhancement of the ozone effect is evident in both skim and whole milk powders and, to a certain extent, at both ozone levels.

The data of Fig. 5 show that, to some extent, whole milk powder suffers greater flavor damage than skimmilk powder when manufactured under an ozone level of 32 ppb. This will be discussed further.

Discussion

The levels of ozone used in our work can be related to naturally occurring ones by the measurements of Heggestad (4). He reported that from July to mid-October for two seasons in the tobacco field six miles northeast of Washington, 25 ppb ozone was the average daily maximum value, 50 ppb the level when plant injury was expected, and 100 ppb very high and infrequent.

Oxidants other than ozone can react in the Mast meter to give positive interference. Nitrogen dioxide, a common air pollutant, interferes in this measurement to the extent of 10% of its molar concentration (7). Sulfur dioxide produces a 100% negative interference on a molar basis; it must be removed if present in an appreciable quantity. This can be done with a chromium trioxide scrubber. Unfortunately, nitric oxide, a common air pollutant, is oxidized in the scrubber to nitrogen dioxide, which

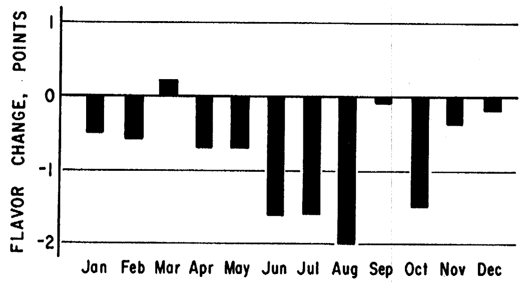

FIG. 3. Seasonal variation in loss of flavor score during manufacture of low-heat, foam-spray-dried milk.

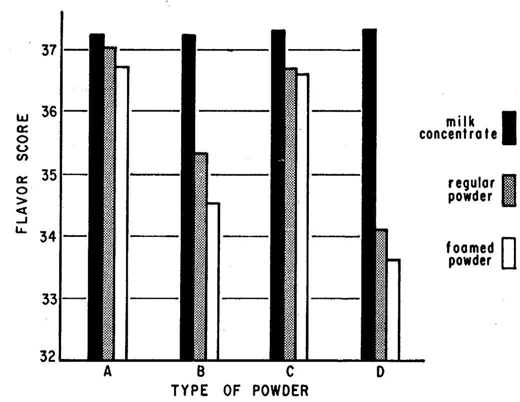

FIG. 4. Effect of surface area on flavor score of dried milks manufactured under two levels of ozone.

A. Skim, 2 ppb ozone; average of three experiments.
B. Skim, 32 ppb ozone; average of three experiments.
C. Whole, 2 ppb ozone; average of two experiments.
D. Whole, 32 ppb ozone; average of two experiments.

adds to the positive interference in the ozone measurements. These interferences can be problems in field measurements of natural air pollution, but were of no consequence in our study, because during this period the background level of oxidants was very low and the added ozone free from interfering materials.

The data of Table 1 show that introduction of 32 ppb ozone into the dryer air had a dramatic effect on the flavor of dried milk. Raising the level to 52 ppb, however, showed little or no further effect. These results agree, in part, with a series of earlier experiments in which the ozone level was controlled by adjusting the oxygen flow rate but could not be measured. The resultant ozone levels are believed to be approximately the same as those in Table 1. Here, too, the highest ozone level had almost no additional effect on whole milk powder but, in contrast, did show increased damage to the flavor of skimmilk powder. It appears that for whole milk powder, at least, the critical ozone levels are lower than 32 ppb. It is noteworthy that all differences in flavor score of experimental samples of one point or more, as noted by our taste panel, are highly significant according to Liming (6).

The data of Berlin et al. (2) indicate that foaming, under our conditions, increases the surface area of whole milk powder about 3.7 times and that of skimmilk powder about 4.6 times. The effect of larger surface areas is to increase the sensitivity of the powders to ozone

TABLE 1. Effect of ozone level on flavor score of dried milks.

Ozone level	Effect on flavor score	
	Skimmilk powder[b]	Whole milk powder[b]
(ppb)	(scores)[a]	
2[c]	—0.5	—0.6
32[d]	—2.2	—3.5
52[e]	—2.6	—3.4

[a] The data represent the number of flavor score points lost in conversion from concentrate to dried milk.
[b] Both foamed and nonfoamed powders are included in averaged figures.
[c] Data on eight skim and four whole milk powders.
[d] Data on six skim and four whole milk powders.
[e] Data on two skim and two whole milk powders.

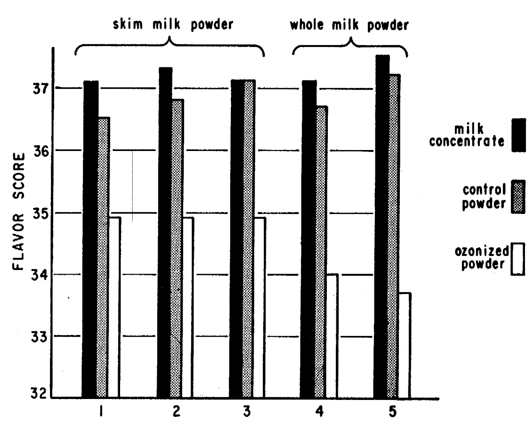

FIG. 5. Effect of fat content on loss of flavor score at 32 ppb. Data represent the average of a foamed and nonfoamed powder in each experiment.

during drying. All of the powders, skimmilk and whole milk, suffered more ozone damage when foamed (Fig. 4); the somewhat greater effect in skimmilk powders parallels their greater increase in surface area during foaming.

It is obvious from the data of Fig. 5 that whole milk powders suffer more ozone damage than skimmilk powders. This suggests that the off flavor is produced by a reaction between ozone and milk fat. On this basis, however, it is puzzling that the observed differences are not greater, since the fat content of whole milk powder is about 30 times that of skimmilk powder. An explanation may have to await an elucidation of the reactions involved.

In conclusion, it can be said that the damaging effect of ozone on flavor quality is serious enough that if the objective is to produce consistently high-quality milk powder, consideration should be given either to locating the plant in an area of low atmospheric pollution or, alternatively, removing the pollutants from the dryer air.

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