EFFECTIVENESS OF VARIOUS VACUUM, TEMPERATURE, AND STEAM TREATMENTS IN REDUCING FEED FLAVORS IN MILK

by

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INTRODUCTION

The factors which are responsible for off-flavors in milk and how to prevent off-flavors have been studied by many investigators. Information has been published concerning the prevention of off-flavors on the farm by the application of specific farm management practices. Very little scientific data have been published on the effectiveness of deodorizing equipment which has been developed for use in milk plants for the removal of off-flavors from milk. The results of research work done in New Zealand by McDowall (31,32,33,34,35,36) and Scott (61,62,63,64,65,66,67,68) dealing with the principle of flavor removing equipment and the application of steam to aid in the removal of off-flavors from lacteal liquids have been published. Recently these investigators have studied the effectiveness of deodorizing in the removal of two reference substances, diacetyl and acetone, from cream. They have worked primarily with plant size equipment which does not lend itself readily to experimental studies. Roberts (54,55) has made some studies in North Carolina on the effectiveness of flavor removing equipment operated under normal plant conditions. Only the procedure recommended by the equipment manufacturer was used, and no attempt was made to vary the operating conditions.

This study was undertaken to determine the effectiveness of three major factors: degree of vacuum, preheat temperature of the milk, and injection of steam from an outside source on the reduction of tainting substances commonly found in milk. Since no plant equipment was available at the time this study was started, it was decided to construct a laboratory apparatus for the removal of off-flavors from milk. This also would permit greater versatility than that provided by the plant size equipment.

McDowall (31) stated that the degree of vacuum applied in the equipment would probably have an effect on the reduction of a taint in milk. In this experiment three degrees of vacuum commonly employed in present day equipment were used.

In line with Scott's (61) theory that flash steam, which is produced when hot milk is introduced into a vacuum chamber, is a factor in the removal of off-flavors, milk was introduced into the vacuum chamber at three different temperatures. The temperatures used include many of those recommended by manufacturers of flavor removing equipment.

There seems to be general agreement among investigators who have studied flavor removal from lacteal liquids that steam from an outside source, rather than flash steam, should be more effective in the removal of off-flavors. Steam is one of the best entrainment agents which can be used because it will maintain the temperature of the milk, volatilize the tainting substance, and is readily available. The laboratory equipment used in this experiment was designed so that steam could be introduced into the vacuum chamber in a counter-current flow to the milk. This made it possible to study the effect of injected steam on flavor removal as compared to treatments without steam injection.

It was postulated that different optimum conditions of operation exist for various types of off-flavors in milk; therefore, the factors studied in this experiment were applied to each of three different off-flavored milks from cows fed silage, alfalfa, and rye.

The results of this study should indicate what conditions should be applied in the flavor removing equipment being used today. It should also reveal whether different conditions will have to be employed to remove specific off-flavors. Through statistical analysis of the data obtained, valid conclusions should be produced. The design of the laboratory equipment will make possible the collection of various fractions of the volatilized tainting substance in condensing traps for their possible identification. This is of prime importance in the future development of flavor removing equipment.

REVIEW OF LITERATURE

Feed Flavor Problem

Basis of Consumption. The most important factor in consumer acceptance of milk is flavor. A clean, fresh, palatable flavor without any objectionable off-flavor is desirable; and any deviation from this standard will be objected to by the consumer (8,49,50,73). According to Nelson, (47) milk flavor is pleasantly sweet, possessing neither fore nor after taste other than a natural richness. Trout (73) stated that the food industry is becoming flavor minded and more emphasis should be placed on milk flavor to protect it against the flavor potential of other foods. He believes that flavor has not been properly evaluated on the quality yardstick in the dairy industry.

Method of Entry to Milk. Feed flavors are common in milk and in some areas 75 percent of the samples examined were criticised as having a feed flavor (4,7,12,20,52,69). An extensive review of literature by Strobel and Babcock (72) reveals that no phase of the dairy industry has received more attention than the milk flavor problem. Off-flavors due to feed may enter the milk by one of the following means: 1) the cow eats feed or weeds causing off-flavor, and the blood carries the flavor producing substance from the digestive system to the udder where it enters the milk, 2) the cow breathes air containing odors which are transferred from the air to the blood stream by the lungs and carried to the udder, 3) feed or weed odors may be absorbed by the milk at milking time directly from the air in the barn (7,35,69). The intensity of off-flavors produced by cows consuming the feeds depends upon the character of the feed, quantity consumed, and time fed in relation to milking (6,51).

Causes and Prevention of Off-Flavors on the Farm

Essentials of Prevention. Control of off-flavors due to feed has been studied extensively by several research workers, and they advocate that all highly flavored feeds should be fed immediately after milking (6,7,19,37,52,53,74,76,79). Smith and Witten (69) outline four essentials in preventing off-flavors in milk: 1) do not supply feeds and weeds that cause an off-flavor, 2) arrange feeding schedule so that five hours or more have elapsed between feeding and milking, 3) eliminate all weeds from pastures, and 4) keep odors out of the milking barn. It was their conclusion that, if enough time had elapsed, the blood stream would eliminate the objectionable flavors by exhalation or the flavors would be carried through the kidneys and excreted.

Causes of Some Specific Feed Off-Flavors. Dairymen know that silage is one of the most economical feeds for dairy cows. Extensive research has shown that corn, alfalfa, grass, and sorghum silage, when eaten by the cow, impart an off-flavor to milk which is highly objectionable and is probably the most frequent feed off-flavor observed (7,16,19,20,30,37). Babcock (7) stated that silage odor was not transmitted into the milk to a disagreeable degree either by the cow breathing the odor or by exposing the milk to an atmosphere containing the odor.

The requirement of keeping cows from eating silage four to five hours before milking may inconvenience the producer or result in decreased production (37).

Alfalfa hay has been observed by several investigators to impart an objectionable taint to milk (16,20,52,76,79). These research workers observed that the cow must eat the hay to impart an off-flavor to the milk. They also observed that a two hour interval from feeding to milking produced the most pronounced off-flavor. The off-flavor produced was not as objectionable to the consumer as the silage but very noticeable.

Rye pasture furnishes an excellent source of nutrients for dairy cows at a time in the fall and spring when other pastures are not available, according to Trout and Horwood (75). They stated that Balbo rye has been used extensively in Kansas, Missouri, Oklahoma, and some other states as a pasture crop. Research on the impartment of an off-flavor by pasturing Balbo rye has yielded conflicting data. Herman and Garrison (25) observed very little change in the milk flavor from pasturing Balbo rye while Trout and Horwood (75) observed an offensive flavor. These investigators and others (5,16,20,79) observed an objectionable off-flavor in milk from cows pastured on ordinary rye. Downs (16) feels that the off-flavor in milk due to rye is next to silage in frequency of occurrence. Most investigators recommend that cows should be removed from rye pasture four to seven hours before milking to prevent tainting of the milk. Flagg (18) stressed the fact that during early pasture season, cows should be kept on pasture only one hour in the morning but that the time may be increased later in the season. He stated that one can of off-flavored milk would taint 2,000 gallons of normal milk. Early removal of cows from pasture is a difficult and time consuming task for the dairyman (37).

Methods of Prevention. Anderson (1) concluded that off-flavored milk was a problem of animal nutrition. He observed a more pronounced off-flavor in milk from feeding field cured alfalfa hay than machine cured. He postulated that the presence of additional carotene in the machine cured hay improved the flavor. Aurand and Moore (2) tested three mineral supplements supplied by a manufacturer on the effect of the prevention of onion flavor in milk. It was concluded that none of the three supplements prevented occurrence of onion flavor; however, improvement resulted in two out of the three tested though only competent judges could detect the difference.

Aeration of the milk immediately after milking has been shown to decrease the intensity of strong feed flavors and has practically eliminated slight feed flavors in the milk (6,7,19,74,76,79). The application of the aeration principle is a problem on the farm unless necessary equipment is available. This equipment may add to the possibility of bacterial contamination (19).

Conventional methods of feed flavor control such as grading in the receiving room, pasture and feed management practices have not been entirely satisfactory. They have resulted in excessive loss to the dairymen for rejected milk and prevented him from using low cost feed. The consumer has continued to get feed flavored milk that reduced consumption (69). The reduction or elimination of feed flavors in the plant may result in increased sales and help to create good will between the dairymen and milk plant (73).

Development of Deodorizing Equipment

Aeration. It has been observed by research workers that cooling milk over open surface coolers and raising lids on vats during pasteurization has reduced the intensity of off-flavors (8,30,54,55,73). Hunziker (29) stated that the principle of aeration was sound enough, but the method applied was utterly inadequate and incapable of removing enough of the off-flavor to accomplish visible improvement in the quality of the milk or cream.

Blowing Air Through Milk and Cream. Over 40 years ago, Ayers and Johnson (3) designed an apparatus for use in removing garlic flavor from milk and cream by means of blowing air through the hot liquid. From 20 to 60 minutes of blowing were required in order to entirely remove the flavor from milk and

40 to 75 minutes when 30 percent butterfat cream was treated. In 1920 Hunziker (29) developed a method and an apparatus for removing volatile and volatilizable odors from sour cream by air treatment. He found the treatment aided in the removal of off-flavors but jeopardized the texture of butter manufactured from the treated cream. The fat in milk has a tendency to become oxidized in flavor more readily when treated with air (MacCurdy and Trout, 30). Hunziker (29) and the Pfaudler Company developed equipment for treating cream by blowing hot air through cream in a glass lined container under partial vacuum. It was found effective in removing volatile off-flavors and did not injure the texture of the butter.

Vacuum Equipment. Vacuum equipment for removal of off-flavors from lacteal liquids was first introduced in New Zealand where the inventor of the process, H. Lamont Murray, (Wilster, 78) did his basic research. He and his father, pioneered the condensed milk industry in New Zealand. Murray (78) observed the elimination of feed flavors when a vacuum was used to lower the temperature in condensing milk. After this observation, he set out to develop a method and an apparatus to remove feed flavors from lacteal liquids by boiling them in a vacuum. Numerous patents were granted to Murray (38,39,40,41, 42,43,44,45,46) in the United States during the years 1924 to 1948. Murray's original idea was to develop an apparatus for deodorizing, cooling, and dehydrating fluids. Briefly his apparatus made it possible to introduce a hot fluid into a vacuum chamber continuously and to remove the fluid intermittently. A steam jacket was placed around the vacuum chamber, and later a method of continuous removal of the treated fluid was developed. In another patent by Murray (43), a vertical cylinder was used for the vacuum chamber and the fluid injected tangentially near the top to obtain a fine film of fluid down the walls of the vacuum chamber. Steam was injected into the milk prior to its entry into the chamber where the vapors were drawn out and condensed by a water cooled condensor. In 1933, Murray (44) patented the method of continuously diffusing steam in direct contact with the flowing, thinned body of liquid within the vacuum chamber for the purpose of raising pasteurization temperature and carrying out the vapors. In 1939, Murray (46) devised a two chamber deodorizer and a two chamber ejector condensor capable of producing two degrees of vacuum. The vacuum was used to pull the liquid into the first container which was the deodorizing section and a higher vacuum used to pull milk into the second or cooling section. Later, Murray (45) developed a pasteurizing section which utilizes steam injection to raise the temperature. By connecting this section to a higher evacuated chamber, the vapors are volatilized and withdrawn from the chamber.

Hornoman (23) devised a means of injecting steam into the liquid prior to its introduction in to the vacuum chamber. A small restriction in the fluid line instantly reduced the liquid to a finely divided state and fog in the vacuum chamber. Thus, the vapor and liquid constituents of the fog can be separated. Hammer, et al. (23) also developed a means for injecting steam into the milk prior to its entrance into the vacuum chamber. They concluded that the entrance line to the chamber must be low enough to prevent entrainment losses and high enough to provide sufficient time for vaporization.

Rogers (57,58,59) patented several apparatuses for deodorizing lacteal liquids. Steam was utilized to raise the temperature as high as 300°F. for short periods prior to discharge the liquid into a vacuum chamber and separated the vapor from the liquid. As a result of these conditions a sterile product was obtained. Other patents (21,22,24,27) have shown slight modifications such as baffles inside the chamber to discharge the liquid downward and outward. The method for maintaining the vacuum within the chamber while introducing the fluid was also patented.

The first machine named the "Vacreator" was manufactured by the Murray Deodorizers Incorporated in New Zealand. By 1939, 75 percent of the butter in New Zealand was manufactured from vacuum treated cream (78). According to Wilster (78) one of the first machines installed in the United States was the "Vacreator" in 1938 at the Oregon State College. The machine was used to study the improvement in quality of cream used for butter making.

Equipment manufacturers in the United States soon became aware of the potential in manufacturing equipment for use in removing off-flavors from milk. They immediately began research on the design of equipment to be used primarily with milk. Fabricius (17) and Bickers (11) stated that if the vacuum treatment did improve the flavor of milk that its use was warranted. They also stated that vacuum equipment should not be used to clean up dirty milk but to improve the flavor of high quality milk. Other research workers (26,54) felt that there was no substitute for a quality procurement program; but if the use of this equipment will permit buying borderline milk and the processor can standardize the flavor, its use is warranted. Roberts (55) believed that vacuum equipment for removing off-flavors could be more appropriately named "flavor standardizers" because of the resulting uniformity in flavor.

Theoretical Basis of Deodorization

Vapor Pressure and Entraining Agents. McDowall (35) stated that many substances have an appreciable vapor pressure, i.e., they throw out a vapor into the free space above them. The free space is saturated when the amount of vapor leaving a liquid is equal to the amount returning. If the substance is not very volatile, the natural vapor pressure at ordinary temperature is much lower than the pressure corresponding to the highest vacuum. The lowest reduced pressure obtainable in vacuum equipment is never below 0.5 inches of mercury or 29.5 inches of applied vacuum. Since the vapor pressure of many tainting substances at temperatures used in vacuum equipment is lower than the minimum reduced pressure, complete removal of a taint from milk or cream can not be achieved.

McDowall's (35) definition of an entraining agent is, "an innocuous gas or vapor used to carry tainting vapors away from the surface of a substance, so rendering the space above unsaturated with respect to the tainting vapor." As a result, further distillation will occur. He stated that it was possible to remove substances which had a vapor pressure lower than the minimum reduced pressure by using a large volume of entraining agent. The principle of using air as an entraining agent might explain why the passing of milk over surface coolers reduces the taint in milk. The principle of entraining vapors is also applied when air is blown through milk. Problems evolve when air is blown through milk with an applied vacuum because the ejector condensor becomes over-loaded with air and water vapor. Water vapor (steam) is the most convenient entraining agent for removing tainting substances from liquids. It is readily available at low cost, maintains the temperature, and can be drawn readily from the liquid by use of a condensor. The effect of increasing temperature on all substances is to increase their vapor pressure. Hence, the higher the milk temperature when steam is used as the entraining agent, the more efficient is the taint removal.

Steam Distillation. According to McDowall (35), steam distillation is the passage of steam through a mixture of substances to remove those which are volatile. Under ideal conditions the current of steam should be passed in countercurrent flow to the current of milk. During treatment the milk would be in contact with steam carrying progressively less tainting vapor. Finally, almost completely deodorized milk would be in contact with clean steam. It is McDowall's (32) opinion that distillation with steam is desirable because it is a convenient carrier of vapor and some substances are very "steam volatile". The factors affecting distillation of tainting substances with steam are the small concentration and the fat and water solubility of the substances. He stated that con-current flow of steam to milk will take up the taint if enough time is allotted for equilibrium of the taint in milk and steam to take place. The amount of taint in the steam varies with: 1) speed of passage of steam to milk, 2) properties of the tainting substance, and 3) milk droplet size.

Nature of Deodorization. McDowall (32) believes that deodorization takes place in two stages, i.e., steam removes substances from the water portion and the substance absorbed in fat is thought to move to the water portion thereby creating a lag in removal. The factors involved in this theory are: 1) size of droplet, 2) amount of convection within droplet, 3) size of fat globule, 4) amount of convection within fat globule, 5) barrier effect of fat globule adsorption layer against rapid passage of substance from fat to serum, 6) properties of tainting substance, and 7) steam volatility. Rate of removal of tainting substances by steam distillation depends in part on the relative volatility of the pure substance, in part on temperature of steam distillation, and in part on the influence of water on vapor pressure of substance in dilute solution (32). Scott (66) believes that the tainting substance may be distributed in the fat, water, or both according to the distribution laws. If during steam stripping or steam distillation the movement of the taint was rapid enough from each of the phases to maintain equilibrium, the computation for removal would be of a single phase system. In the extreme, the movement of the taint from the fat globule might be slow, which is possible; therefore, size of the fat globule has an effect. In all probability when the fat globules are small, the movement of the taint will be as that in a single phase. In the case of the large globule clusters, the taint is probably removed from the serum first. The concentration of the taint is reduced and further removal must be obtained by subsequent deodorizations. Scott (66) concluded that the conditions needed to be known are: the nature of the substance, relative solubility in fat and water, and the boiling points or vapor pressure curves of the substance. Since very few of the substances are known, the properties are not known.

McDowall's (35) views on removal of gases from milk are that raising the temperature and lowering the pressure assist the removal. Application of vacuum and raising the temperature have in some respects opposing effects. If the vacuum is high, the solubility of the gas in the liquid becomes lower. However, the reduction in pressure also reduces the boiling point, the temperature, and the tendency of the gas to leave the liquid. Therefore, the application of a high vacuum may not be the best method of removing gaseous contaminants from lacteal liquids. At ordinary temperatures, the number of possible gaseous contaminants are small compared to the liquid and solid tainting substances. Liquids and solids differ from gases in that their solubilities in other substances are usually increased by a rise in temperature. Again, contrasting conditions occur when a rise in temperature is employed. The volatility of the tainting substance is increased; however, it increases the solubility of the taint in the liquid. Equations can be derived for the degree of removal of a taint when it is insoluble in the water or fat, by use of the vapor pressure curves of the tainting substance. Vacuum equipment can remove only substances which have an appreciable vapor pressure at the temperature of treatment. Many bitter tasting substances have no odor. Because their vapor pressure is so low, the quantity volatilized is insufficient to affect the sense of smell. Vacuum equipment cannot remove this type of substance. Contaminating substances in milk or cream may be gases, liquids, or solids at ordinary temperatures and some may be soluble in fat and/or water (35).

Flash Steam and Open Steam. Scott (66) stated that flash steam is evolved when a liquid is allowed to flow into a vessel held at some pressure below the saturation pressure corresponding to a temperature of the incoming liquid. Flash steam will be formed and the taint concentration in this steam will be in equilibrium with the concentration of the taint in the outgoing liquid. He stated that the use of open steam or steam from an outside source is advantageous in that it can be used to prevent concentration of the liquid. According to McDowall, (35) the optimum conditions of running vacuum equipment will vary with the type of taint involved. He concluded that the following principles apply: 1) insoluble substances will be removed more readily than soluble substances of the same degree of volatility, 2) most substances will be more readily removed at higher temperatures of treatment, i.e., under low vacuum, and 3) removal of all tainting substances in a short period of treatment is dependent upon their entrainment by steam. It was his opinion the advantages of vacuum equipment are that they provide a means of continuous steam distillation of taints from milk or cream with minimum severity of heat treatment. The main functions of the applied vacuum are to control the severity of heat treatment, to assist in rapid removal of taint laden water vapor, and to replace pumps in drawing the liquid through the machine.

Analysis of Existing Equipment

Classification of Equipment. Equipment manufacturers have been trying for several years to perfect equipment that will volatilize or remove off-flavors from milk (Roberts, 54). Vacuum equipment can be classified into three main categories under which there are several modifications (54,61). In Type I there is no direct injection of steam and pasteurization does not occur in the flavor removing equipment. The raw milk is drawn by vacuum from the balance tank through the regenerator section of a high temperature short time (H.T.S.T.) pasteurizer and heated to approximately 138°F. From the regenerator the milk goes to the first vacuum chamber where air and noncondensable gases are removed. No boiling occurs in this chamber. Next the milk is pumped from the first vacuum chamber to the H.T.S.T. pasteurizer and the temperature is raised to 162°F. or any temperature up to 200°F. depending upon the treatment desired. The milk enters the second chamber tangentially and flashes immediately, the volatile flavors being removed in the flash steam by vacuum. After this exposure, the pasteurized milk goes through regenerator and cooling sections of the H.T.S.T. and is ready for packing. A series of spray pans are located in the first chamber of some equipment to prolong exposure. The flash steam vapors from the second chamber are sometimes passed through the first chamber where some condensation occurs. This replaces some of the water lost due to "flashing". Some manufacturers recommend the use of one chamber only, and it usually functions like the second chamber described above (Roberts, 54). Scott (61) classified this type of equipment as steam generators. He stated that allowing the hot milk or cream to enter an evacuated chamber does not generate enough steam to remove a large amount of the taint. He thinks that the primary advantage of this type of chamber is for cooling the fluid after treatment.

Type II equipment, as described by Roberts (54,55) used direct steam injection sufficient to raise the temperature to 195°F. but still did not meet pasteurization requirements. They are usually tied in with a H.T.S.T. pasteurizer where the milk is discharged at 162°F. and drawn into the first chamber. The temperature in this chamber can be raised by injection of live steam up to 195°F. or some intermediate temperature. Then milk is drawn by vacuum into a second chamber where more boiling occurs and temperature is dropped to about that at which it enters the first chamber. The milk is atomized or sprayed into the first chamber and enters tangentially into the second chamber. A centrifugal pump removes milk from the final chamber and sends it through the heat exchanger for cooling. Modifications of the Type II machines are the use of a steam heating tube and a single vacuum chamber. The milk is heated to the desired temperature in a stainless steel tube with steam and the mixture released under vacuum. Scott (61) classified this type of equipment as con-current and mixing. Roahen and Mitten (53) described a commercial machine which followed the description of the Type II vacuum equipment.

Type III as classified by Roberts (54,55) is equipment which uses an excess of steam and may be used as a pasteurizer. It can be used with H.T.S.T. or with plate heat exchangers that have a heating and cooling section. The raw milk is heated and enters the first chamber at approximately 140°F. where live steam is injected to raise temperature to 194°F. to meet pasteurization requirements. Speck (71) reported that a temperature of 194°F. in Type III equipment is recognized by the United States Public Health Service Ordinance to be equally efficient as temperatures required for vat pasteurization. Controls permit the maintenance of temperature while additional quantities of steam are added (Barber, 9). The product is discharged by vacuum into second and third chambers where additional flavor removal results (Roberts, 54). Scott's (61) classification is that of a continuous counter-current flow type equipment where distillation with open steam is used. The simplest method is to spray the liquid downward against an uprising flow of steam or by letting the liquid flow down a vertical wall with steam flowing upward through the cylinder. Behlmer (10) describes the flow through a commercial machine of Type III.

Problems of Equipment. When live steam is injected into milk it must be free of compounds that will exhibit off-flavors. It should be free from rust, relatively dry, and low in superheat. Many compounds used in treating boiler feed water volatilize in the steam and cause a taint in the milk product. The Food and Drug Administration has declared some of these compounds toxic and prohibit their use. When proper precautions are taken, live steam may be used for the removal of off-flavors and the production of a high quality product can be obtained without danger of off-flavors from steam impurities (Roberts, 54).

Roberts (55) described the problem of concentration during treatment as a serious threat to manufacturers' profits. Dilution of the product is illegal. Machines vary considerably because of radiation losses and the amount of superheat in steam. He observed that when the temperature of the milk discharged was considerably lower than the incoming milk that concentration resulted. The range of temperature over which concentration may occur may be as great as 2 to 15°F. depending on equipment and installation. When a low or negative temperature difference is maintained, dilution takes place provided steam is used in the heating and deodorizing treatment. If no steam is used, the temperature difference must equal radiation losses or concentration will result. Barber (9) described several automatic controls which had been developed and were quite accurate in maintaining preset temperature differences. These controls are required to meet pasteurization requirements.

The cream line is damaged by any treatment which increases the temperature of heating or time of holding above minimum pasteurization requirements. Steam injection and atomization cause partial churning and oiling which will reduce the cream line of milk (54,55).

Effectiveness of Existing Equipment. Roberts (54,55) concluded that all machines Type I, II, and III reduced the intensity of feed flavors present. The improvement in flavor was found to be related to intensity of steam treatment. He stated that vacuum treatment alone does not appear to remove the quantity of feed flavor desired by the dairy plant operator. His beliefs are that a strict grading program must be maintained when using Type I machines. Type II machine operators use a minimum amount of steam during off-season and maximum during off-flavor season. Type III machines removed satisfactorily all feed and weed flavors with exception of bitterweed and spoiled silage.

McDowall (31) in his experiments utilized two reference substances, diacetyl and acetone for the study of effectiveness of treatments. He stated that these reference substances have been studied and are thought to include many of the actual properties tainting of substances. McDowall (32) concluded that the solubility of diacetyl in butterfat and water increases with temperature while acetone stays constant over a temperature change. McDowall (36) worked with a continuous vaporization apparatus to determine the vapor/liquid equilibrium coefficients for diacetyl and acetone. The equilibrium coefficient was derived from Raoult's Law and Henery's Law (32). The boiling points and vapor pressures of the two reference substances differ greatly, so many tainting substances may be included. Scott (66) also utilized these two reference substances and concluded that flashing cream without steam showed little reduction for a low volatile substance but removed high volatile substances almost as well as when live steam was used. McDowall (34) concluded that with the use of cream, steam is most effectively used if applied in separate stages instead of one stage. Removal was not affected by an increase in rate of flow of cream and steam at a constant intensity of treatment.

Removal of diacetyl was not affected by temperature of steam distillation over a range of 138° to 197°F.; but with acetone, there was a progressive reduction in extent of removal with decrease in distillation temperature. He also studied effects of changing the position of the steam inlet pipe and placing baffles in the uptake pipe between chambers and concluded that removal of taints was only slightly affected.

Scott (68) described a counter-current flow of cream to steam apparatus which he believes to be a more efficient means of removing volatile tainting substances. Since equilibrium is never attained in practical counter flow columns the degree of taint removal is associated with rate of taint transfer. An alternate method to continuous counter flow is multiple contact counter flow whereby two or more mixing stages reaching equilibrium within each stage are arranged in counter flow. In 1956, Scott (65) devised a laboratory apparatus to study the rate of taint transfer in a counter flow stripping column. He arranged a sampling tube within the vacuum chamber to determine the taint concentration at various levels within the chamber. Results of this experiment showed that resistance to transfer of taint depends on a liquid-side resistance and a steam-side resistance. The action of the milk as it was passing through the chamber was as a spray or falling film. Wilster (78) concluded from his experiments with the "Vacreator" that it: 1) generally improved flavor, 2) removed feed and weed flavors,

3) improved the body and texture of the butter, 4) improved keeping quality of butter, 5) more efficiently destroyed bacteria, and 6) brought greater market returns. McDowall (33) observed in some recent experimental work that lactose depresses the vapor/liquid equilibrium coefficient for diacetyl in cream and thus decreases the rate of removal. Lactose had no effect on the acetone vapor/liquid coefficient. He also observed that sodium chloride in solution caused a rise in the equilibrium coefficient for both diacetyl and acetone.

A summary of McDowall's (31) experiment indicates that the following factors will influence the effectiveness of a treatment 1) temperature of pasteurization of cream prior to vacuum treatment, 2) degree of vacuum applied in the primary steam distillation chamber which controls temperature of steam distillation, 3) location of inlet pipe for injection of steam in excess of that required for heating cream to pasteurization temperature, 4) effectiveness of single treatment with steam as compared with several successive treatments with smaller amounts of steam, 5) comparison of con-current flow of steam with counter-current flow, and 6) relation of volume of flow, i.e., time of contact of steam and cream, to effectiveness of steam distillation treatment obtained. He suspected that optimum conditions for treating will differ to the type of tainting substance encountered.

Efficiency of Existing Equipment. It has been observed that the efficiency of the Type III equipment as a means of removing taints suggests that economy measures could be taken (34,54,55,68). Scott (63,64) who has done extensive work in the study of off-flavor removal explains a new technique to increase economy in the "Vacreator". He terms the method as "steam stitching" which is the application of the counter flow principle of steam in a multiple stage unit. This technique enables increased cream flow rate without increasing steam input; thus, cutting operating time with a proportional saving in steam usage. An alternate method would be to keep cream flow and off-flavor removal constant with a reduction of approximately 50 percent in steam consumption. In this improved method two or more deodorizers are used with the steam moving in counter flow to the cream and in this way partially tainted steam establishes a new equilibrium with highly tainted fresh cream. Steam stitching has led to difficulties of overloading the condenser; however, by use of higher pressure condenser water or larger condensers and/or use of second condenser, the problem can be solved. Scott (62) also described an "Economajor" which is a surface condenser designed to condense some of the steam passing to the ejector condenser thereby heating fresh water for washing or boiler feed water.

Laboratory Apparatuses. Roberts et al. (56) in 1940 devised a laboratory apparatus in which steam could be injected con-currently with a stream of milk and this mixture released into a glass container under vacuum. Their experiment was designed primarily to compare this type of pasteurization to vat pasteurization in terms of bacterial destruction, butterfat losses, and flavor. The apparatus which Scott (65) used to study taint transfer rate was on a pilot plant scale. He stressed the point that experimental work could be done on small scale equipment. Brown et al. (13) have done extensive work on heat processing of fluid foods since 1951 on a pilot plant scale.

Future Development

McDowall (31), in 1953 at the International Dairy Congress, stated that although this type of flavor removing equipment has been in use three decades there has been no scientific study of the influence of different conditions of operation on the extent of taint removal. Patton and Keeney (49) stated that no attempts have been made to identify the compounds responsible for feed type flavors. Roberts (54) also stated that little was known about the chemical nature of substances which impart an off-flavor to milk. A summary of information presented at a flavor symposium held in Chicago in 1957 was that food flavors are the most important single factor in selection of foods and consumption of foods. The benefits of food flavor research are: 1) better natural flavor, 2) more effective prevention of off-flavor, 3) development of improved synthetic flavors, 4) reduction or elimination of ripening and aging processes for flavor development, and 5) improved palatability of foods. The members of the symposium stated that the surface of flavor chemistry has been only scratched and the greatest essential in flavor analysis, as in other analytical work, is a reliable tool. They believe that paper and column chromatography are indispensable, and gas chromatography is rapidly becoming a powerful tool in separating non-volatile substances after converting them to volatile derivatives. They stated that chemical characterization of flavor substances follows four basic steps: isolation, concentration, purification, and identification (50).

EXPERIMENTAL PROCEDURE

Description and Construction of Equipment

Laboratory Scale. In view of the widespread interest in the removal of off-flavors from milk it was decided to conduct further research on this problem. The equipment used for this purpose is designed primarily for milk plant operation. It is not only costly, but also it is designed to handle large volumes of milk. McDowall (31) and Scott (67) have indicated that there is great possibility of studying various factors effecting removal of off-flavors from milk by using laboratory size equipment. It seemed advisable to construct an all glass apparatus to study the factors. A laboratory apparatus offers several advantages such as; the rapid variation of conditions applied, utilization of a small sample, and the ability to observe the conditions of operation. The advantage of being able to run numerous samples in a short length of time also is of importance in securing enough data for statistical analysis.

Before attempting to design and construct the laboratory apparatus, the literature was reviewed to obtain as much information as possible on how to construct an all glass system. Several manufacturers of deodorizing equipment were contacted and the principle of their equipment studied. Sanderson (60) gave considerable basic information on the use of vacuum pumps, manometers, condensers, and the art of glass blowing. Weissberger (77) presented a very thorough introduction to the theory of distillation and the design of laboratory vacuum apparatuses. Brown (14) explained the equilibrium between the vaporous state and liquid state as well as information on the construction of laboratory equipment. Additional ideas and advice were furnished by Dr. . D. Rutz and other staff members of the Kansas Agricultural Experiment Station, working on the project.

General Description. The apparatus is more adequately described as a continuous distillation with or without the injection of open steam. In general the apparatus consists of a milk reservoir, preheater, steam generator, vacuum chamber, water cooled condenser and receiver, product receiver, manometer, and vacuum pump. A photograph of the actual apparatus constructed is presented in Plate I. A more detailed diagram is presented in Plate II. The entire apparatus was assembled on a five by seven foot aluminum grating mounted on a laboratory bench. This grating aided the rigidity and the flexibility of the various parts of the apparatus. Pyrex glass was used throughout the apparatus with the exception of a few joints which were connected with Tygon tubing.

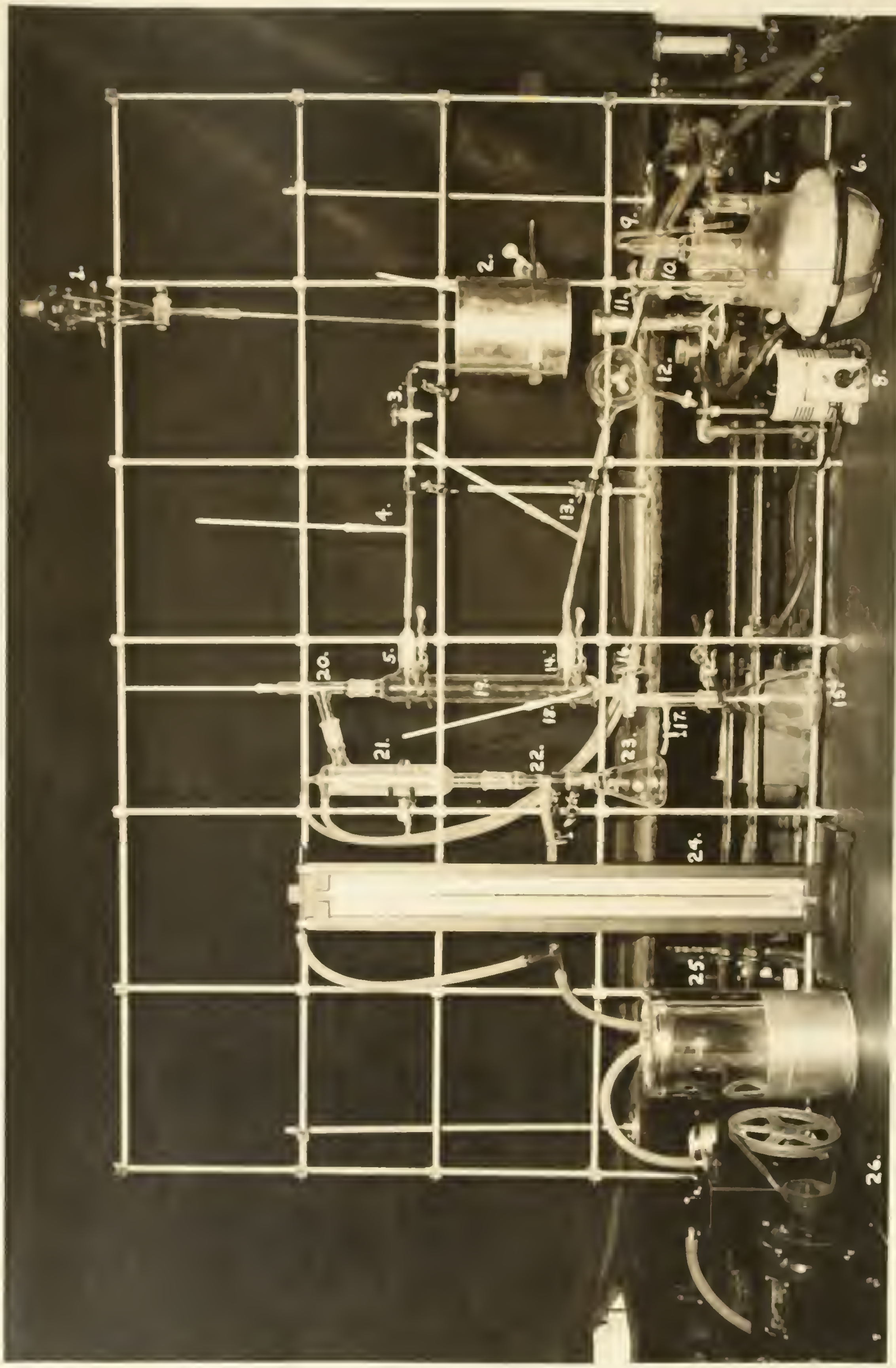
Milk Section. The milk reservoir, which was a 300 ml. separatory funnel, was mounted 23 inches above the preheating coil. The milk line to the preheater was four mm. in diameter. The preheating coil was constructed from four mm. glass tubing and was two inches wide by six inches long. The coil was suspended in a water bath which was heated with a Meker burner. A two-way stopcock was inserted in the milk line to the vacuum chamber to regulate the flow and serve as a vacuum breaker to the atmosphere. Also a thermometer was inserted in the milk line next to the vacuum chamber. A special orifice constructed from glass was fitted into a standard taper opening in the chamber for atomization of the milk in a downward direction.

EXPLANATION OF PLATE I

Laboratory apparatus for removing off-flavors from milk

1. Milk reservoir
2. Preheating coil and water bath
3. Milk flow rate control valve
4. Thermometer for entering milk temperature
5. Milk atomizing orifice
6. Glas-Col heating mantle
7. Steam generating flask
8. Variable voltage transformer
9. Steam pressure outlet
10. Steam valve
11. Meker burner for heating water bath
12. Steam condensate trap
13. Thermometer for steam temperature
14. Steam atomizing orifice
15. Erlenmeyer flask for treated milk
16. Stopcock to control rate of outgoing milk
17. Vacuum release clamp
18. Thermometer for outgoing milk temperature
19. Vacuum chamber
20. Thermometer for outgoing vapor temperature
21. Friedrichs condenser
22. Vacuum connecting tube
23. Erlenmeyer flask for condensate
24. Sargent mercury manometer
25. Dewar flask with freezing trap
26. Cenco mechanical vacuum pump

PLATE I

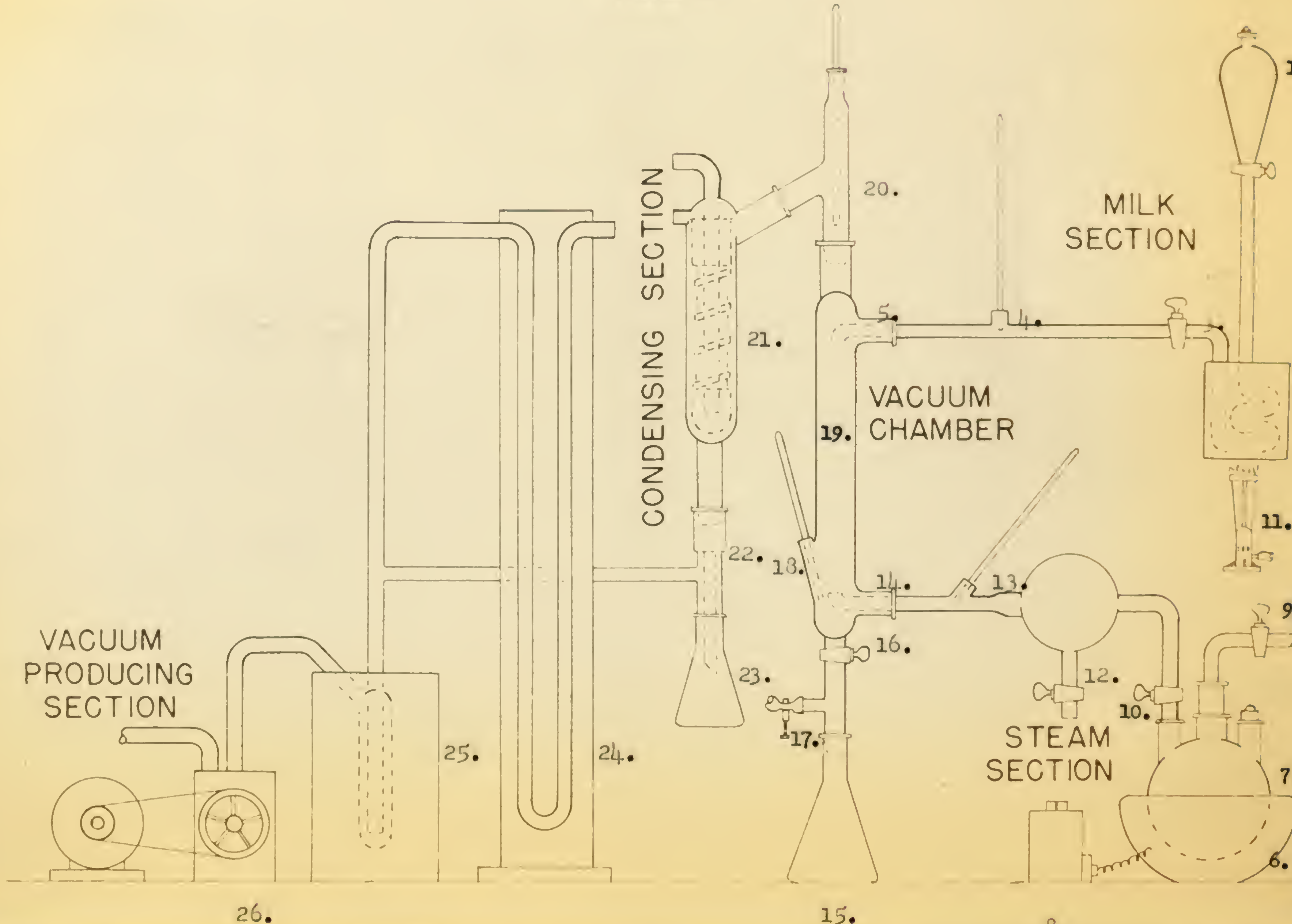


EXPLANATION OF PLATE II

Diagram of Laboratory Apparatus for Removing Off-Flavors from Milk

1. Milk reservoir
2. Preheating coil and water bath
3. Milk flow rate control valve
4. Thermometer for entering milk temperature
5. Milk atomizing orifice
6. Glas-Col heating mantle
7. Steam generating flask
8. Variable voltage transformer
9. Steam pressure outlet
10. Steam valve
11. Meker burner for heating water bath
12. Steam condensate trap
13. Thermometer for steam temperature
14. Steam atomizing orifice
15. Erlenmeyer flask for treated milk
16. Stopcock to control rate of outgoing milk
17. Vacuum release clamp
18. Thermometer for outgoing milk temperature
19. Vacuum chamber
20. Thermometer for outgoing vapor temperature
21. Friedrichs condenser
22. Vacuum connecting tube
23. Erlenmeyer flask for condensate
24. Sargent mercury manometer
25. Dewar flask with freezing trap
26. Cenco mechanical vacuum pump

PLATE II



MILK SECTION
VACUUM CHAMBER
CONDENSING SECTION
STEAM SECTION
VACUUM PRODUCING SECTION
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2.
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This orifice could be turned to obtain atomization in any direction. The opening of the orifice was extremely small and was positioned in the exact center of the chamber and two inches from the top of the chamber.

Vacuum Chamber. The heart of this apparatus is the vacuum chamber, specifically constructed for use in this experiment. It was two inches in diameter and 18 inches long. Three standard taper openings were constructed in the cylinder. They were 24 mm. in diameter and 40 mm. in length of the taper. One of the openings was situated at the top for passage of the vapors into the condenser. Another opening situated two inches below the top was for the milk orifice fitting. The third opening was situated two inches above the base of the chamber for the steam injection orifice. A stopcock was attached to the base of the chamber to regulate the flow of outgoing liquid. A 500 ml. Erlenmeyer flask was attached below this stopcock on the base of the chamber to collect the product. A thermometer was inserted in the side of the chamber to determine the temperature of the milk during treatment. A vacuum breaker was inserted below this stopcock so the receiver could be removed without breaking vacuum in the entire system.

Steam Section. Steam, from the college power plant was tried and discarded because it contained taints resulting from chemicals used in the boiler water treatment process. Steam for injection was produced from distilled water in a 3000 ml. three-necked flask surrounded by a Glas-Col heating mantle. A pressure regulating stopcock was attached to one neck and a plug inserted into the second neck of the flask. From the generator steam was conducted into an especially constructed condensate trap by means of a stopcock and past a thermometer inserted in the four mm. glass line. An orifice of the same design as for the milk inlet was used to atomize the steam upward in a counter-current flow to the milk. For the treatments without steam this orifice could be removed and a plug inserted in the chamber opening. A variable voltage transformer was used to control the heat for producing steam. It would be desirable to have steam under higher pressure than that produced in a glass container so an excess could be driven through the chamber; however, this was unavailable at the time of this experiment.

Condenser Section. A connecting tube was attached to the top of the vacuum chamber to carry the vapors into the condenser. A thermometer was inserted in this tube to determine the temperature of the outgoing vapor. A Friedrichs condenser was used to condense the vapors. A connecting tube designed to attach a vacuum source was placed between the condenser and receiver. The receiver was a 300 ml. Erlenmeyer flask. A trap for freezing out any vapors that were not condensed by the water cooled condenser was also included. The trap was suspended in a Dewar flask containing dry ice and ethanol which provided a temperature of -78°C. This trap was used primarily to prevent any vapors from entering the vacuum pump.

Vacuum Producing Section. A Cenco mechanical vacuum pump was used to produce a vacuum. The reduced pressure in the chamber was observed by means of a mercury manometer attached to the vacuum line.

Experimental Design

Basis of Experiment. Equipment manufacturers are now selling milk deodorizing equipment to milk plants, yet a search of the literature reveals only a limited amount of scientific data on the optimum conditions for the operation of this equipment. This experiment was undertaken to study some of the major factors affecting the removal of tainting substances from milk.

The factors included in this study were the degree of vacuum, preheating temperature of the milk, and steam injection. The three off-flavors included in this study were those found in milk from cows which had been fed silage, alfalfa hay, and pastured on rye.

Study of Various Off-Flavors. The milks used in these experiment were produced by three groups of three cows each, two Holstein and one Jersey from the Kansas State College dairy herd. The cows were fed silage or alfalfa hay two to three hours before milking. In the trials using milk from cows pastured on rye, the concentrate ration was withheld one feeding before they were pastured on Balbo rye. The milk was obtained at three different times. The first and second quantities of milk were divided into two lots each. The third quantity of milk was not divided; thus, five lots of off-flavored milk were obtained for the various treatments. Each lot of raw milk was scored before treatment. By dividing the quantities of milk the reproduciability of the treatment could be determined and by using milk from several cows the composition variance of milk from individual cows was eliminated as a factor. The milk was cooled promptly to 35°F. and stored at that temperature approximately 12 to 48 hours before treatment for removal of off-flavors. Improvement in flavor was measured by the difference in the numerical score of the milk before and after treatment. The samples were scored by four experienced milk judges who were members of the Dairy Department staff. The score card and system of scoring was that used in the International Collegiate Students' Judging Contests. The samples were numbered in such a manner that their identity was not known by the judges.

Study of Various Vacuums. As indicated by the review of literature, various degrees of evacuation may have an influence on the reduction of an off-flavor in milk. Each of the three different off-flavored milks were subjected to three degrees of vacuum; 9, 19, and 29 inches of mercury or 533, 278, and 25 mm. of mercury of reduced pressure respectively. The relationship of inches mercury of vacuum to mm. mercury reduced pressure is presented in Table 36 in the Appendix. After running a few trials the data were discussed with Dr. Stanley Wearden in the Statistics Department. It was determined that five observations per treatment combination were needed to detect a difference of a given size at the 0.05 level of probability. Since the temperature of the milk within the chamber will vary with the applied vacuum, this factor can not be varied without injection of steam from an outside source.

Study of Various Preheat Temperatures. It was considered highly desirable to determine the effect, if any, of varying the temperature of the milk prior to entrance into the vacuum chamber. Three temperatures of 140°, 160°, and 174°F. were used in this experiment. These temperatures were used for each of the various vacuums which were applied to each of the off-flavors. The same number of duplications were required to determine significance at the 0.05 probability level as were required for the various vacuums.

Study of Injection of Open Steam. Roberts (54), McDowall (31), and Scott (61) stated that the use of steam as an entraining agent aids the removal of off-flavors. McDowall (31) and Scott (68) both stated that theoretically counter-current flow of steam to milk should prove to be most effective in reducing the intensity of a tainting substance. This apparatus was designed so that the counter-flow of steam could be used. Open steam was injected at each of the various vacuums and preheat temperatures used with the three different off-flavored milks. These combinations made it possible to make comparisons in 45 different trials with and without steam injection. This number of trials provided enough data to determine significance at the 0.05 probability level.

Determination of Optimum Conditions. It was considered desirable to determine the optimum combination of the various factors studied for each of the off-flavors. By means of statistical methods the most desirable combination of factors was determined for each of the three off-flavored milks.

Processing Procedures

Various Vacuums and Preheat Temperatures Without Steam. The operation of the apparatus to achieve the treatments without steam and at constant temperature were as follows. Approximately 300 ml. of the off-flavored milk was placed in the milk reservoir at 35°F. The water bath surrounding the preheating coil was then heated to secure the desired temperature of milk passing through the coil. The vacuum pump was next turned on and the desired vacuum regulated by the use of a pinch clamp on the vacuum line. After evacuation of the system and regulation of the desired vacuum, the stopcock at the base of the milk reservoir was opened and milk allowed to flow through the preheating coil, through the rate regulating valve, past the thermometer, and through the orifice into the vacuum chamber. Ten minutes elapsed while 300 ml. of milk were drawn through the apparatus or at the rate of 1.8 liters per hour. The liquid portion of the milk falls to the bottom of the chamber and was collected in an Erlenmeyer flask which was cooled in an ice water bath. The vaporous phase was drawn upward and out of the chamber and condensed. When the desired quantity of milk had passed through the apparatus, the stopcock at the base of the vacuum chamber was closed and the receiver removed with the product. The treated product was then cooled and stored at 35°F. until it was scored. All samples were scored within 36 hours after treatment.

Various Vacuums and Preheat Temperatures with Steam Injection. The modification in the processing procedure for the treatments with steam included the removal of the plug from the vacuum chamber and insertion of the steam atomizing orifice. The steam generator was then connected to this orifice and steam injected through the chamber in an upward flow. After the steam had been passing through the chamber for several minutes, the flow of milk was turned on and the samples collected in the same manner as done for treatments without steam.

General Procedure and Cleaning of Equipment. The system was rinsed between trials by running distilled water through it. The apparatus was completely disassembled at the end of each day and between two different off-flavors for a thorough cleaning with a detergent. The vacuum chamber and orifices were cleaned with either a chromic acid or strong alkali solution.

If any of the factors varied during the course of a sample, the product receiver was removed and a new one replaced when the conditions had been standardized. The first 25 to 30 ml. of product were discarded and only milk which had received the specified treatment saved. Considerable time was saved by being able to remove the product receiver without breaking the vacuum in the entire system. In this study no attempt was made to measure the intensity of the taint in the vapor condensate; however, it was observed that an odor existed in the condensed vapor from the off-flavored milk.

EXPERIMENTAL RESULTS

The results of this experiment will be presented separate for each feed off-flavor studied. A statistical analysis was made on the factors studied for each off-flavor. The analysis of variance (Snedecor, 70) was used to determine whether significant differences existed between the variables studied. The Duncan's Multiple Range Test (70) was used to detect which variable was significantly different from another.

Effectiveness of Treatments on Silage Off-Flavor

Quality of Raw Milk. Silage off-flavored milk was obtained and divided as described in the experimental procedure. The numerical flavor score of the five lots of milk ranged from 35 to 36 with a mean score of 35.7. The actual flavor scores for each lot of untreated milk used are presented in Tables 15 to 20 in the Appendix. The panel of judges indicated independently that all the lots of untreated milk possessed a definite to pronounced silage flavor and odor.

Various Preheat Temperatures of Milk. In the first series of experiments with silage off-flavored milk, six trials consisting of five lots of milk or the total of 30 lots of milk were subjected to each different preheat temperature before they were introduced into the vacuum chamber. The three preheat temperatures used were 140°, 160°, and 174°F. and they were controlled within a plus or minus 2°F. The effectiveness of the treatment was measured by taking the difference between the score of the untreated and treated milk. In all cases there was an improvement in the flavor of the treated milk. The flavor score differences for each lot of milk are tabulated in Tables 15 to 20. The mean flavor score difference for the milk in each of the trials employing the use of the three preheat temperatures are presented in Table 1.

Table 1. Effectiveness of three preheat temperatures of milk on the removal of silage off-flavor by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference 140°F.	Trial No.	Flavor score difference 160°F.	Trial No.	Flavor score difference 174°F.
1	2.1	4	1.5	7	1.4
2	2.1	5	1.6	8	1.6
3	1.9	6	1.8	9	1.5
10	2.4	13	1.6	16	1.2
11	2.3	14	2.3	17	1.4
12	1.7	15	1.7	18	1.5
Mean	2.067		1.733		1.433

[1] Compiled from data in Tables 15 to 20 (Appendix).

It may be observed in Table 1 that the 140°F. preheat temperature improved the mean flavor score difference of the milk 2.067 points, the 160°F. temperature 1.733 points, and the 174°F. temperature 1.433 points. The summary of the analysis of variance (Table 33) shows that the flavor score difference between the three preheat temperatures was very highly significant. The Duncan's Multiple Range Test was used to determine which preheat temperature was significantly different. It was concluded that the 140°F. preheat temperature was more effective than the 160° or 174°F. and the 160°F. temperature was more effective than the 174°F. All these differences were found to be significant.

Various Degrees of Vacuum. The silage off-flavored milks were treated at 9, 19, and 29 inches of applied vacuum. The flavor scores of the treated milk at the three applied vacuums were presented in Tables 15 to 20. Thirty lots of milk were treated under each degree of vacuum and the mean flavor scores for each trial are compiled in Table 2.

Table 2. Effectiveness of three vacuums on the removal of silage off-flavor from milk by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference 9"	Trial No.	Flavor score difference 19"	Trial No.	Flavor score difference 29"
1	2.1	2	2.1	3	1.9
4	1.5	5	1.6	6	1.8
7	1.4	8	1.6	9	1.5
10	2.4	11	2.3	12	1.7
13	1.6	14	2.3	15	1.7
16	1.2	17	1.4	18	1.5
Mean	1.667		1.883		1.683

[1] Compiled from data in Tables 15 to 20 (Appendix).

Milk subjected to 19 inches of vacuum had a mean flavor score improvement of 1.883 points which was higher than the 9 and 29 inch vacuum flavor scores which were 1.667 and 1.683 points respectively. An analysis of variance was run on the flavor score difference and a summary of this analysis was presented in Table 33 in the Appendix. The value obtained for F was not significant at the 0.05 probability level but significant at the 0.10 level. Application of the Duncan's test to the flavor score differences indicated that there was a significant improvement in the flavor of the 19 inch vacuum compared to the 9 and 29 inch vacuum treatments.

When milk was subjected to the 29 inches of vacuum, it was observed that it boiled violently. The appearance of the milk in the vacuum chamber at the two lower vacuums was of a falling film nature. The film of milk covered the entire wall surface of the vacuum chamber when the milk orifice was positioned at the correct angle.

Steam vs. No Steam Injection. Steam from an outside source was injected into 45 lots of silage flavored milk as described in the experimental procedure. The flavor score differences of the milk as a result of the steam and no steam treatments were recorded in Tables 15 to 20. The quantity of steam passing into the chamber was measured by the amount condensed and collected in the trapping system which was employed. No concentration or dilution of the milk was observed when steam was used. Thus, the quantity of steam condensed should serve as the basis of the intensity of the steam treatment. When the rate of milk flow through the chamber was 1800 ml. per hour, 380 ml. of steam condensate was obtained per hour. The intensity of the steam treatment can be stated as 1 ml. of steam condensate for each 4.70 ml. of milk passing through the chamber. The steam temperature varied between 208° to 212°F. depending upon the vacuum in the chamber. The mean flavor score difference for each trial with and without steam is compiled in Table 3.

Table 3. Effectiveness of steam vs. no steam injection treatment on the removal of silage off-flavor by comparison of mean flavor score differences.[1]

Trial No.	Flavor score difference No steam	Trial No.	Flavor score difference Steam
1	2.1	10	2.4
2	2.1	11	2.3
3	1.9	12	1.7
4	1.5	13	1.6
5	1.6	14	2.3
6	1.8	15	1.7
7	1.4	16	1.2
8	1.6	17	1.4
9	1.5	18	1.5
Mean	1.711		1.778

[1] Compiled from data in Tables 15 to 20 (Appendix).

It may be observed in Table 3 that the treatments without steam injection improved the mean flavor score 1.711 points as compared to 1.778 points with steam injection. The summary of analysis of variance in Table 33 reveals that this is not a significant difference.

Optimum Combination of Factors. The trials with each preheat temperature were run with each degree of vacuum and with and without steam injection. The statistical analysis included the calculation for a significant interaction between any two variables or the combination of the three variables studied. The test for an interaction between temperature and vacuum revealed a significant difference between the combinations at the 0.10 probability level. The ranked means for each combination is presented in Table 4.

Table 4. Effectiveness of various combinations of preheat temperatures on the removal of silage off-flavor by ranking the means of the flavor score differences.[1]

Treatment Combinations Temperature - Vacuum	Ranked mean flavor score difference
174° - 9"	1.30
174° - 19"	1.50
174° - 29"	1.50
160° - 9"	1.50
160° - 29"	1.75
140° - 29"	1.80
160° - 19"	1.95
140° - 9"	2.20
140° - 19"	2.20

[1] Compiled from data in Tables 10 to 15 (Appendix).

The Duncan's test was used to determine which combinations were significantly different. The two combinations, 140° F. preheat temperature with both 9 and 19 inches of applied vacuum were significantly more effective than the other combinations with the exception of the 160°F. temperature with 19 inches of vacuum. The 174° F. temperature with the low vacuum of 9 inches was the least effective temperature-vacuum combination.

The statistical analysis indicates no significant difference between any of the other combinations of factors studied in this experiment with silage off-flavored milk. However, these interactions are approaching significance and with the comparison of more trials a significant difference might be shown.

Effectiveness of Treatments on Alfalfa Off-Flavor

Quality of Raw Milk. The milk used for this series of trials was obtained and divided into five lots as described in the experimental procedure. The five lots of milk ranged in numerical flavor score between 35 and 36 with a mean score of 35.4. The actual scores of the untreated milk are tabulated in Tables 21 to 26. Each lot of untreated raw milk was criticised for having a definite or pronounced alfalfa off-flavor which would be objectional to the consumer.

Various Preheat Temperatures of Milk. The same preheat temperatures were used on the alfalfa off-flavored milks that were used with silage off-flavored milk. Also, the same number of lots of milk were treated with each preheat temperature to determine the effectiveness of the treatment. The measure of effectiveness used was the difference in flavor score between the untreated and treated milk scores. The flavor score differences for each lot of milk are tabulated in Tables 21 to 26. All the treated milk had a higher flavor score than the untreated milk. The mean flavor score differences as a result of the various preheat temperatures applied to alfalfa off-flavored milk are compiled in Table 5.

Table 5. Effectiveness of three preheat temperatures of milk on removal of alfalfa off-flavor by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference 140°F.	Trial No.	Flavor score difference 160°F.	Trial No.	Flavor score difference 174°F.
1	1.8	4	2.3	7	2.2
2	1.6	5	2.4	8	2.3
3	1.6	6	2.3	9	2.6
10	2.5	13	2.5	16	2.3
11	2.4	14	2.4	17	2.8
12	2.2	15	2.7	18	3.0
Mean	2.017		2.433		2.533

1 Compiled from data in Tables 21 to 26 (Appendix).

The mean flavor score difference for the 140°, 160°, and 174°F. preheat temperatures were 2.017, 2.433, and 2.533 points respectively. From the summary of the analysis of variance (Table 34) it was concluded that the differences were very highly significant. With application of the Duncan's test it was concluded that the 160° and 174°F. temperatures were significantly more effective than the 140°F. temperature. There was no significant difference between the effect of the 160° and the 174°F. preheat temperatures.

Various Degrees of Vacuum. Three degrees of vacuum were applied to the alfalfa flavored milk in the same manner as employed with silage flavored milk. The flavor score difference resulting from the different lots of milk treated with the three degrees of vacuum are tabulated in Tables 21 to 26. Thirty lots of milk were treated with each vacuum and the mean flavor score differences for each trial are compiled in Table 6.

Table 6. Effectiveness of three vacuums on removal of alfalfa off-flavor from milk by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference 9"	Trial No.	Flavor score difference 19"	Trial No.	Flavor score difference 29"
1	1.8	2	1.6	3	1.6
4	2.3	5	2.4	6	2.3
7	2.2	8	2.3	9	2.6
10	2.5	11	2.4	12	2.2
13	2.5	14	2.4	15	2.7
16	2.3	17	2.8	18	3.0
Mean	2.367		2.317		2.40

[1] Compiled from data in Tables 21 to 26 (Appendix).

The mean flavor score differences for the 9, 19, and 29 inch vacuum treatments were 2.367, 2.317, and 2.400 points respectively. A summary of the analysis of variance (Table 34) was employed with the vacuum treatment flavor score differences. No significant difference was obtained between the different degrees of vacuum used in this series of trials for removing alfalfa off-flavor from milk.

Steam vs. No Steam Injection. Nine trials consisting of five lots each or a total of 45 lots of milk with an alfalfa off-flavor were subjected to the steam injection treatment described in the experimental procedure. The flavor score difference as a result of this treatment was compared to those without steam injection. Tabulation of the flavor score differences are presented in Tables 21 to 26. A summary of the mean flavor score differences for each trial is presented in Table 7.

Table 7. Effectiveness of steam vs. no steam injection treatment on the removal of alfalfa off-flavor by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference No steam	Trial No.	Flavor score difference Steam
1	1.8	10	2.5
2	1.6	11	2.4
3	1.6	12	2.2
4	2.3	13	2.5
5	2.4	14	2.4
6	2.3	15	2.7
7	2.2	16	2.3
8	2.3	17	2.8
9	2.6	18	3.0
Mean	2.122		2.533

1 Compiled from data in Tables 21 to 26 (Appendix).

The mean flavor score improvement for all the trials without steam was 2.122 points. The treatments with steam injection increased the flavor score a mean of 2.533 points. The summary of analysis of variance (Table 34) indicates that the difference is very highly significant. It can be concluded that the steam treatment was definitely more effective in removing alfalfa off-flavor than treatment with no steam.

<u>Optimum Combination of Factors</u>. In order to arrive at the optimum combination of factors or method of treatment which produced the greatest improvement in flavor score, all possible combinations of factors were taken into consideration. The analysis of variance included the test for an interaction between any combination of the factors. The summary of the analysis of variance (Table 34) indicates a significant interaction between temperature and vacuum at the 0.10 probability level. The ranked means of flavor score differences of each combination of temperature and vacuum are presented in Table 8.

Table 8. Effectiveness of various combinations of temperature and vacuums on removal of alfalfa off-flavor by ranking the mean flavor score differences.[1]

Treatment Combinations Temperature - Vacuum	Ranked mean flavor score difference
140° - 29"	1.90
140° - 19"	2.00
140° - 9"	2.15
174° - 9"	2.25
160° - 9"	2.40
160° - 19"	2.40
160° - 29"	2.50
174° - 19"	2.55
174° - 29"	2.80

[1] Compiled from data in Tables 21 to 26 (Appendix).

With application of the Duncan's test the 174°F. preheat temperature with 29 inches of applied vacuum was found to be significantly more effective than the other combinations as it improved the flavor score 2.80 points. There also was a significant difference between the temperature-vacuum combinations which improved the flavor score 2.25 and 2.40 points.

The analysis of variance also indicates significance for the combinations of temperature with and without steam at the 0.10 probability level. The mean flavor score difference for each combination was ranked and is presented in Table 9.

Table 9. Effectiveness of various combinations of temperature and steam on the removal of alfalfa off-flavor by ranking the mean flavor score differences.[1]

Treatment Combinations Temperature - Steam	Ranked mean flavor score difference
140° - N	1.667
160° - N	2.333
174° - N	2.367
140° - S	2.367
160° - S	2.533
174° - S	2.700

[1] Compiled from data in Tables 21 to 26 (Appendix).
N No steam injection.
S Steam injection.

With use of the Duncan's test the 174°F. preheat temperature with steam injection was found to be significantly more effective than the other combinations with the exception of the 160°F. temperature with steam injection. The 140°F. temperature without steam injection was significantly the least effective combination. By ranking the means of the flavor score differences it is evident that as the preheat temperature increases and with steam injection that the flavor score increases. Other combinations of the factors studied did not yield significant differences in their effectiveness.

Effectiveness of Treatments on Rye Off-Flavor

Quality of Raw Milk. Off-flavored milk from cows pastured on rye was obtained and divided into five lots as described in the experimental procedure. The five lots of milk had a mean flavor score of 35.5. The flavor scores are tabulated for each lot of milk in Tables 27 to 32. The untreated milk was criticized by the panel of judges as having a definite or pronounced grassy off-flavor, commonly observed when the cows had been pastured on Balbo rye. This set of trials was run in April when the pasture was first being used. The cows used for this experiment were placed on the pasture several times without obtaining a pronounced rye off-flavor. However, after the cows had been pastured on rye for six successive days the off-flavor in the milk was highly objectionable.

Various Preheat Temperatures of Milk. In this series of trials with rye flavored milk; the milk was subjected to the same treatments and number of trials that were used with the previous off-flavors studied. All the flavor score differences were improvements over the untreated milk. The data for each lot of milk were tabulated in Tables 27 to 32. The mean flavor score differences for each trial with each preheat temperature are presented in Table 10.

Table 10. Effectiveness of three preheat temperatures of milk on the removal of rye off-flavor by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference 140°F.	Trial No.	Flavor score difference 160°F.	Trial No.	Flavor score difference 174°F.
1	1.8	4	2.2	7	1.9
2	1.7	5	2.4	8	2.4
3	1.8	6	2.2	9	2.6
10	3.1	13	2.7	16	2.4
11	2.9	14	3.3	17	2.9
12	2.8	15	3.1	18	3.0
Mean	2.350		2.850		2.583

[1] Compiled from data in Tables 27 to 32 (Appendix).

The mean flavor score improvement for the 140°, 160°, and 174°F. preheat temperatures were 2.35, 2.85, and 2.583 points respectively. The summary of the analysis of variance (Table 35) indicates that there is a significant difference between the three temperatures at the 0.05 probability level. With the application of the Duncan's Multiple Range Test it was concluded that the 160°F. temperature was significantly more effective than either the 140° or 174° F. temperatures. The results of the test also show that the 174°F. temperature was significantly more effective than the lowest or 140°F. preheat temperature.

__Various Degrees of Vacuum.__ The three degrees of vacuum used in this series of trials to study their effect, if any, on the removal of rye off-flavor from milk, were the same as those used previously. The flavor score difference for each lot of milk as a result of the various degrees of vacuum were tabulated in Tables 27 to 32. The mean flavor score differences from each of six trials run with each vacuum are presented in Table 11. In this study six trials consisting of 5 lots each or the total of 30 comparisons were made.

Table 11. Effectiveness of three vacuums on the removal of rye off-flavor from milk by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference 9"	Trial No.	Flavor score difference 19"	Trial No.	Flavor score difference 29"
1	1.8	2	1.7	3	1.8
4	2.2	5	2.4	6	2.2
7	1.9	8	2.4	9	2.6
10	3.1	11	2.9	12	2.8
13	2.7	14	3.3	15	3.1
16	2.4	17	2.9	18	3.0
Mean	2.367		2.634		2.583

1 Compiled from data in Tables 27 to 32 (Appendix).

The mean flavor score improvement for the 9, 19, and 29 inches of applied vacuum were 2.367, 2.634, and 2.583 points per lot respectively. The summary of the analysis of variance (Table 35) indicates that there is a significant difference between the three vacuums used. As a result of applying Duncan's test it was concluded that the 19 and 29 inch vacuums were significantly more effective in removing rye off-flavor than the nine inch vacuum. There was no significant difference between the 19 and 29 inch vacuums.

<u>Steam vs. No Steam Injection</u>. This series of trials employed the use of steam as an entraining agent for the tainting substance. Forty-five lots of rye flavored milk were treated with steam injection and 45 without. Only the counter-current flow method of steam injection was studied. The improvement in flavor score for each lot of milk was tabulated in Tables 27 to 32. The mean flavor score differences for each trial are presented in Table 12.

Table 12. Effectiveness of steam vs. no steam injection treatments on the removal of rye off-flavor from milk by comparison of the mean flavor score differences.[1]

Trial No.	Flavor score difference No Steam	Trial No.	Flavor score difference Steam
1	2.1	10	3.1
2	1.7	11	2.9
3	1.8	12	2.8
4	2.2	13	2.7
5	2.4	14	3.3
6	2.2	15	3.1
7	1.9	16	2.4
8	2.4	17	2.9
9	2.6	18	3.0
Mean	2.134		2.922

[1] Compiled from data in Tables 27 to 32 (Appendix).

It may be observed in Table 12 that the treatments without steam improved the flavor score 2.134 points compared to 2.922 points for treatments with steam injection. The summary of the analysis of variance (Table 35) indicates that the difference was very highly significant. It may be concluded from the observation of the two mean flavor score differences that the milk treated with steam from an outside source was considerably more effective than those without steam injection.

Optimum Combination of Factors. To determine the optimum conditions of operation for the most effective method of rye off-flavor reduction, all combinations of factors were studied. The summary of the analysis of variance (Table 35) indicates a significant difference between the various combinations of preheat temperature and vacuum. The actual flavor score differences for each combination was recorded in Tables 27 to 32. The mean flavor score difference for each possible combination were ranked in Table 13.

Table 13. Effectiveness of various combinations of preheat temperatures and vacuums on the removal of rye off-flavor by ranking the mean flavor score differences.[1]

Treatment Combinations Temperature - Vacuum	Ranked mean flavor score difference
174° - 9"	2.20
140° - 19"	2.30
140° - 29"	2.30
140° - 9"	2.45
160° - 9"	2.45
160° - 29"	2.65
174° - 19"	2.75
174° - 29"	2.80
160° - 19"	2.85

1 Compiled from data in Tables 27 to 32 (Appendix).

The application of Duncan's test indicates that the 160°F. preheat temperature with 19 inches of vacuum was the most effective but not significantly different from the three combinations lower in flavor score improvement. The 174°F. preheat temperature with nine inches of vacuum was the least effective but not significantly different from the two higher flavor score improvements.

The interaction of preheat temperature with and without steam injection also yielded a significant difference in the resulting flavor score differences. The summary of the analysis of variance (Table 35) shows that this interaction is highly significant. The ranked means of flavor score differences for the various combinations are presented in Table 14.

Table 14. Effectiveness of various combinations of preheat temperatures and steam injection on the removal of rye off-flavor by ranking the mean flavor score differences.[1]

Treatment Combinations Temperature - Steam	Ranked mean flavor score difference
140°F. - N	1.700
160°F. - N	2.267
174°F. - N	2.367
174°F. - S	2.800
140°F. - S	2.934
160°F. - S	3.033

[1] Compiled from data in Tables 27 to 32 (Appendix).

[N] No steam injection.

[S] Steam injection.

With the use of the Duncan's test, it was concluded that the 140°F. temperature was significantly the least effective combination observed. The 160°F. temperature with steam injection was the most effective as it increased the flavor score a mean value of 3.033 points. This combination was not significantly more effective than the two combinations ranked lower in Table 14.

There was no significant combination of the three factors; preheat temperature, vacuum, and steam as indicated by the summary of the analysis of variance (Table 35). A significant combination of factors might be detected if more comparisons were made.

DISCUSSION OF RESULTS

Since the introduction of equipment for the removal of off-flavors from lacteal liquids, several installations have been made in dairy plants. No references were found on the effects of varying the degree of vacuum on removing specific feed off-flavors from milk. No research has been reported on the effect of different forewarming temperatures of the milk prior to introduction into the vacuum chamber. McDowall (31) and Scott (66) have made extensive studies on the effect of using steam from an outside source, as an entraining agent on the removal of off-flavors from cream. Roberts (55) observed the operation of the different types of equipment used for removing off-flavors from milk. He found that the amount of off-flavor removal was related to the intensity of the steam treatment. He reported that vacuum treatment without steam injection did not appear to remove the amount of off-flavor desired by most dairy plant operators.

This experiment included the study of the effects of three different preheat temperatures of milk, three degrees of vacuum, and steam injection on the removal of specific feed off-flavors from milk. To determine the optimum conditions of operation, the above factors were studied in all possible combinations. Before this experimental work could be started, it was necessary to construct a laboratory apparatus which could be used to study the effects of varying conditions of operation on off-flavor removal. Several changes and modifications were made before a satisfactory laboratory apparatus was constructed. The apparatus used in this experiment was described in the experimental procedure.

Theoretically, the temperature of the milk upon entrance into the vacuum chamber is a major factor affecting the amount of off-flavor removal. Three temperatures were used and the results of their use with silage off-flavored milk indicate that the lower or 140°F. temperature was more effective than either the 160° or 174°F. preheat temperatures. Partial explanation for the increased effectiveness of the lower temperature is thought to be in the amount of cooked flavor obtained at the higher temperatures of treatment. According to theory a liquid or solid tainting substance would become more soluble in the milk with increasing temperature; thus, more difficult to remove with increasing temperature. The effect of the different temperatures on removing an alfalfa off-flavor were that the higher temperature or 174°F. was the most effective and the 160°F. was more effective than the lower or 140°F. preheat temperature. Theoretically, the more flash steam evolved, the more effective the treatment. The higher preheat temperature has the most flash steam produced so it is postulated that this is the reason for the increased effectiveness. Results of the trials on the rye flavored milk indicated that the 160°F. temperature was considerably more effective than either the higher or lower temperatures of treatment. From these results it may be concluded that different preheat temperatures may be desirable for reduction of different feed off-flavors. The 140°F. preheat temperature was found to be best for the silage off-flavor, the 160°F. was best for the rye flavored milk, and the 174°F. was the most effective for the alfalfa flavored milk.

Three degrees of applied vacuum were studied with each off-flavor. On silage off-flavor, the 19 inch vacuum appeared to be the most effective; however, the difference in flavor score of the milk between vacuums was not as great as between various temperatures. Explanation for the 19 inch vacuum being more effective than the nine inch vacuum lies in the fact that the corresponding temperature of the milk within the vacuum chamber was not as high as that under the nine inch vacuum. The observation that the lower preheat temperature was the most effective might indicate that a 29 inch vacuum would be the most effective because of its corresponding low temperature. However, the results do not indicate this relationship. There was no significant difference in flavor score differences observed in the trials using various degrees of vacuum to remove alfalfa off-flavor. However, all the vacuums used in this series increased the mean flavor score 2.3 points or more. The effect of the different vacuums on the removal of rye off-flavor showed that the 19 inch vacuum was the most effective; however, it was not significantly different from the 29 inch vacuum. Both these vacuums were significantly more effective than the nine inch vacuum. The increased amount of flash steam, as a result of the higher vacuums, appears to be important in removing rye off-flavors from milk. The observation of the vigorous action of the milk within the vacuum chamber under the high vacuums, provides logic that the off-flavor substance should be volatilized.

Steam was injected counter-currently to the flow of milk and the effect of this treatment compared to those without any steam injection. The effect of the steam treatment on removing silage off-flavor showed no significant difference in flavor score. Partial explanation lies in the fact that the higher temperatures of treatment did not improve the flavor score as much as the lower temperatures of treatment on silage off-flavor. A more pronounced cooked flavor was observed when steam was injected under the high preheat temperatures of milk; thus, the flavor score was reduced. It appears that the silage off-flavor does not need steam treatment to be adequately reduced in milk. From these results it would appear to be uneconomical to use steam injection when it did not remove any more of the off-flavor than the vacuum treatment alone. The effect of injecting steam on the removal of alfalfa off-flavor from milk indicates that it definitely aided the removal. The increase of the mean flavor score of the alfalfa flavored milk was 2.5 points with steam injection. This increase was the highest improvement of the various factors studied with alfalfa flavored milk. The results of the effect of steam injection on removing rye off-flavor also gave proof that it definitely aided the removal. The lots of milk were improved by a mean flavor score of 2.9 points per lot. Almost complete elimination of the rye off-flavor was observed with steam injection at the optimum preheat temperature of 160°F. for rye flavored milk.

It is apparent from the results obtained in this study that different optimum operating conditions are required for removal of specific feed off-flavors from milk. The most desirable combination for removing silage off-flavor was the 140°F. preheat temperature with 9 or 19 inches of applied vacuum. The optimum treatment for removing alfalfa off-flavor was the 174°F. preheat temperature with 29 inches of vacuum. This combination gives the larger amount of flash steam which theoretically should give the most effective treatment when steam from an outside source is not used. It was observed that the combination of 174°F. preheat temperature with steam injection was nearly as effective as the above combination for removing alfalfa off-flavor. It is postulated that the substance or substances exhibiting an alfalfa off-flavor have a low degree of volatility due to the fact that the most effective treatment was the one producing the greatest quantity of flash steam. The most desirable combination of preheat temperature and vacuum for removing rye off-flavor was the 160°F. with 19 inches of vacuum. Both these factors are intermediate in the degrees used in this experiment explaining possibly that the rye flavor substances are of intermediate volatility. The most desirable treatment for removing rye off-flavor from milk was the combination of 160°F. preheat temperature with steam injection.

Each of the various treatments studied in this experiment improved the flavor score of the milk. The treatments with the 174°F. preheat temperature and 19 inches of vacuum produced a cooked flavor in the milk. The untreated milk flavor was not observed to be exceptionally poor; however, all the untreated milk had a definite feed flavor. It may be observed that the optimum treatment varies for each flavor studied; therefore, it may be desirable to know exactly what type of flavor is in the milk and the most effective treatment then applied. The results of this experiment must be interpreted on the basis that the various treatments were made with a laboratory apparatus. Further research work should be undertaken with plant equipment to qualify the results obtained in this experiment under laboratory conditions.

SUMMARY AND CONCLUSIONS

The purpose of this experiment was to determine the effects of varying preheat temperature, vacuum, and steam injection on the reduction of feed off-flavors in milk. Emphasis was placed on the importance of operating conditions varying in desirability for different feed off-flavors.

Considerable time was devoted to designing and constructing a laboratory apparatus which could be used to study the various factors affecting off-flavor removal. A total of 270 lots of milk were processed through the apparatus for this experiment. Each lot of milk was scored by a panel of four judges who scored the milk independently. This resulted in a total of 1080 individual flavor score observations. The results of this experiment will be summarized with each specific feed off-flavor studied.

The summary of results on treatments employed with silage off-flavor indicate:

1. The 140°F. preheat temperature was more effective in reducing silage off-flavor than the 160° or 174°F. temperatures.
2. The 19 inch vacuum treatment was more effective than the 9 or 29 inch vacuums applied to silage off-flavored milk.
3. The use of steam from an outside source did not aid the removal of silage off-flavor from milk.
4. The optimum combination of factors studied for reducing silage off-flavor in milk was the 140°F. preheat temperature with either 9 or 19 inches of applied vacuum. These treatments improved the flavor score of the milk 2.2 points.

Results of the study on treatments affecting the removal of an alfalfa off-flavor from milk are summarized as follows:

1. The 174°F. preheat temperature was the most effective temperature studied in reducing the intensity of alfalfa off-flavor; however, it was not significantly more effective than the 160°F. preheat temperature.
2. There was no significant difference observed between the various vacuums on reduction of alfalfa off-flavor;

however, all the vacuum treatments studied removed a large portion of the off-flavor.

3. The use of steam injection from an outside source aided the removal of the alfalfa off-flavor from milk in every treatment studied.

4. The most desirable combination of preheat temperature and vacuum was the 174°F. with 29 inches of vacuum which improved the flavor score 2.8 points. The most effective combination of preheat temperature and steam or no steam was 174°F. temperature with steam injection which improved the flavor score 2.7 points.

The results of the various treatments on reducing rye off-flavor in milk indicate:

1. The 160°F. preheat temperature was the most effective temperature used in reducing rye off-flavor in this experiment.

2. The use of 19 inches of applied vacuum appeared to be the most effective vacuum treatment; however, it was not significantly more effective than the 29 inch vacuum.

3. It was shown that the use of steam injection on reducing rye off-flavor definitely aided the reduction of the off-flavor.

4. The optimum combination of preheat temperature and vacuum was 160°F. with 19 inches of vacuum which improved the flavor score 2.85 points. The optimum combination of preheat temperature and the use of steam or no steam injection was 160°F. with the use of steam which improved the flavor score 3.30 points.

It may be concluded from this study that the use of flavor removing equipment does improve the flavor of milk with a silage, alfalfa, or rye off-flavor. It also can be concluded that the flavor of the milk can be made more uniform from day to day by subjecting the milk to the optimum treatments described in this study. The results of this experiment justify the installation of flavor removing equipment, however, the cost of plant equipment may be prohibitive to some dairy plants. Future study on the practicality of installing flavor removing equipment should be considered. This would include the determination of the amount of increased sales as a result of the improved flavor and whether this increase would offset the initial cost and operating cost of the equipment. It must be noted that these conclusions represent the results of treatments applied in a laboratory apparatus which simulated plant equipment. Future study should be undertaken to qualify the conclusions of this experiment for plant equipment by doing research with pilot plant or actual plant size equipment.

This research project has only introduced some of the many possibilities of study in removing off-flavors from milk. Some of these possibilities are the study of removing additional off-flavors from milk, study of various methods of steam injection (con-current vs. counter-current), study of varying the design of equipment (use of several vacuum chambers for multiple stage deodorization), and the isolation, purification, and identification of the actual chemical compounds responsible for the specific off-flavors in milk.

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APPENDIX

Table 15. Improvement in the flavor score of silage flavored milk preheated to 140°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Temperature milk °F. Outlet	Temperature milk °F. Difference	Reduced pressure mm. Hg.	Milk score Initial	Milk score Treated	Milk score Difference	Flavor treated milk
1	1	139.0	130.0	9.0	533.0	35.5	37.5	2.0	s. feed
	2	142.0	126.0	16.0	533.0	35.0	37.0	2.0	d. feed
	3	140.0	124.0	16.0	533.0	36.0	38.0	2.0	s. feed
	4	140.0	131.0	9.0	533.0	36.0	38.0	2.0	s. feed
	5	140.0	125.0	15.0	533.0	36.0	38.5	2.5	v.s. feed
	Mean	140.2	127.2	13.0	533.0	35.7	37.8	2.1	
2	1	140.0	106.0	34.0	270.0	35.5	37.5	2.0	s. feed
	2	138.0	104.0	34.0	278.0	35.0	37.5	2.5	s. feed
	3	142.0	111.0	31.0	282.0	36.0	38.0	2.0	s. feed
	4	140.0	111.0	29.0	280.0	36.0	38.0	2.0	s. feed
	5	140.0	107.0	33.0	278.0	36.0	38.0	2.0	s. feed
	Mean	140.0	107.8	32.3	277.6	35.7	37.8	2.1	
3	1	140.0	68.0	72.0	20.0	35.5	37.5	2.0	s. feed
	2	140.0	70.0	70.0	21.0	35.0	37.0	2.0	d. feed
	3	140.0	77.0	63.0	25.0	36.0	38.0	2.0	s. feed
	4	140.0	73.0	67.0	24.0	36.0	38.0	2.0	s. feed
	5	140.0	70.0	70.0	21.0	36.0	37.5	1.5	s. feed
	Mean	140.0	71.6	68.4	22.2	35.7	37.6	1.9	

s. - slight
v.s. - very slight
d. - definite

Table 16. Improvement of flavor score of silage flavored milk preheated to 160°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
4	1	160.0	130.0	30.0	533.0	35.5	36.5	1.0	d. feed
	2	158.0	127.0	31.0	533.0	35.0	36.5	1.5	d. feed
	3	159.0	132.0	27.0	533.0	36.0	37.5	1.5	d. feed
	4	159.0	131.0	28.0	533.0	36.0	37.0	1.0	d. feed
	5	160.0	131.0	29.0	533.0	36.0	38.0	2.0	s. feed
	Mean	159.2	130.2	29.0	533.0	35.7	37.2	1.5	
5	1	160.0	113.0	47.0	278.0	35.5	36.5	1.0	d. feed
	2	160.0	120.0	40.0	278.0	35.0	36.5	1.5	d. feed
	3	160.0	121.0	39.0	278.0	36.0	37.5	1.5	d. feed
	4	159.0	122.0	37.0	278.0	36.0	38.0	2.0	s. feed
	5	160.0	115.0	45.0	278.0	36.0	38.0	2.0	s. feed
	Mean	159.8	118.2	41.6	278.0	35.7	37.3	1.6	
6	1	159.0	76.0	83.0	25.0	35.5	36.5	1.0	d. feed
	2	159.0	76.0	83.0	25.0	35.0	37.0	2.0	d. feed
	3	160.0	78.0	82.0	26.0	36.0	38.0	2.0	s. feed
	4	161.0	77.0	84.0	25.0	36.0	38.0	2.0	s. feed
	5	159.0	75.0	84.0	24.0	36.0	38.0	2.0	s. feed
	Mean	159.6	76.4	83.2	25.0	35.7	37.5	1.8	

s. - slight
v.s. - very slight
d. - definite

Table 17. Improvement in the flavor score of silage flavored milk preheated to 174°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
7	1	174.0	158.0	16.0	533.0	35.5	37.5	2.0	s.f. - d.c.
	2	176.0	158.0	18.0	533.0	35.0	36.5	1.5	d.f. - d.c.
	3	173.0	163.0	10.0	533.0	36.0	37.0	1.0	s.f. - d.c.
	4	172.0	155.0	17.0	533.0	36.0	37.5	1.5	s.f. - d.c.
	5	172.0	145.0	27.0	533.0	36.0	37.0	1.0	s.f. - d.c.
	Mean	173.4	155.8	17.6	533.0	35.7	37.1	1.4	
8	1	173.0	127.0	46.0	278.0	35.5	37.5	2.0	s.f. - s.c.
	2	176.0	120.0	56.0	278.0	35.0	36.0	1.0	d.f. - s.c.
	3	174.0	130.0	44.0	278.0	36.0	37.5	1.5	d.f. - s.c.
	4	173.0	120.0	53.0	278.0	36.0	38.0	2.0	s.f. - s.c.
	5	172.0	120.0	52.0	278.0	36.0	37.5	1.5	s.f. - s.c.
	Mean	173.6	123.4	50.2	278.0	35.7	37.3	1.6	
9	1	173.0	76.0	97.0	25.0	35.5	37.0	1.5	d.f. - s.c.
	2	174.0	77.0	97.0	25.0	35.0	36.0	1.0	d.f. - s.c.
	3	174.0	78.0	96.0	26.0	36.0	37.5	1.5	d.f. - s.c.
	4	175.0	77.0	98.0	25.0	36.0	38.0	2.0	s.f. - s.c.
	5	174.0	77.0	97.0	25.0	36.0	37.5	1.5	d.f. - s.c.
	Mean	174.0	77.0	96.8	25.1	35.7	37.2	1.5	

s.f. - slight feed
d.f. - definite feed
s.c. - slight cooked
d.c. - definite cooked

Table 18. Improvement in the flavor score of silage flavored milk preheated to 140°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Temperature milk °F. Outlet	Temperature milk °F. Difference	Reduced pressure mm. Hg.	Milk score Initial	Milk score Treated	Milk score Difference	Flavor treated milk
10	1	140.0	195.0	+55.0	533.0	35.5	37.5	2.0	s. feed
	2	140.0	196.0	+56.0	533.0	35.0	37.5	2.5	s. feed
	3	140.0	196.0	+56.0	533.0	36.0	38.0	2.0	s. feed
	4	140.0	196.0	+56.0	533.0	36.0	38.5	2.5	s. cooked
	5	140.0	196.0	+56.0	533.0	36.0	38.5	2.5	s. cooked
	Mean	140.0	195.8	+55.8	533.0	35.7	38.0	2.3	
11	1	141.0	164.0	+23.0	275.0	35.5	37.5	2.0	s. feed
	2	142.0	167.0	+25.0	278.0	35.0	38.0	3.0	s. feed
	3	141.0	167.0	+23.0	278.0	36.0	38.5	2.5	s. feed
	4	140.0	167.0	+27.0	278.0	36.0	38.0	2.0	s. feed
	5	139.0	167.0	+28.0	278.0	36.0	38.0	2.0	s. feed
	Mean	140.6	166.0	+25.4	278.0	35.7	38.0	2.3	
12	1	142.0	106.0	36.0	40.0	35.5	36.5	1.0	d. feed
	2	140.0	106.0	36.0	30.0	35.0	37.0	2.0	d. feed
	3	140.0	106.0	36.0	30.0	36.0	37.5	1.5	s. feed
	4	140.0	110.0	30.0	35.0	36.0	38.0	2.0	s. feed
	5	140.0	113.0	27.0	35.0	36.0	38.0	2.0	s. feed
	Mean	140.4	108.2	32.2	34.0	35.7	37.4	1.7	

s. - slight
d. - definite

Table 19. Improvement in the flavor score of silage flavored milk preheated to 160°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Temperature milk °F. Outlet	Temperature milk °F. Difference	Reduced pressure mm. Hg.	Milk score Initial	Milk score Treated	Milk score Difference	Flavor treated milk
13	1	158.0	195.0	+37.0	533.0	35.5	36.5	1.0	d.f. - s.c.
	2	158.0	194.0	+36.0	533.0	35.0	36.5	1.5	d.f. - s.c.
	3	158.0	194.0	+36.0	533.0	36.0	37.5	1.5	s.f. - s.c.
	4	160.0	196.0	+36.0	533.0	36.0	38.0	2.0	s.f. - s.c.
	5	160.0	196.0	+36.0	533.0	36.0	38.0	2.0	s.f. - s.c.
	Mean	158.0	195.0	+36.0	533.0	35.7	37.3	1.6	
14	1	158.0	164.0	+ 6.0	278.0	35.5	38.0	2.5	s. cooked
	2	158.0	167.0	+ 9.0	278.0	35.0	36.5	1.5	d. feed
	3	160.0	165.0	+ 5.0	278.0	36.0	38.5	2.5	s. cooked
	4	160.0	165.0	+ 5.0	278.0	36.0	38.5	2.5	s. feed
	5	160.0	167.0	+ 7.0	278.0	36.0	38.5	2.5	s. feed
	Mean	159.2	165.6	+ 6.4	278.0	35.7	38.0	2.3	
15	1	160.0	106.0	54.0	45.0	35.5	37.5	2.0	s. feed
	2	159.0	112.0	47.0	48.0	35.0	36.0	1.0	d. feed
	3	160.0	111.0	49.0	40.0	36.0	37.5	1.5	d. feed
	4	159.0	110.0	49.0	35.0	36.0	38.0	2.0	s. feed
	5	160.0	114.0	46.0	35.0	36.0	38.0	2.0	s. feed
	Mean	159.6	110.6	49.0	40.6	35.7	37.4	1.7	

s.f. - slight feed
d.f. - definite feed
s.c. - slight cooked

Table 20. Improvement in the flavor score of silage flavored milk preheated to 174°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
16	1	172.0	196.0	+24.0	533.0	35.5	36.5	1.0	s.f.-d.c.
	2	170.0	194.0	+24.0	533.0	35.0	36.0	1.0	s.f.-p.c.
	3	173.0	195.0	+22.0	533.0	36.0	37.0	1.0	s.f.-d.c.
	4	173.0	195.0	+22.0	533.0	35.0	37.0	2.0	s.f.-d.c.
	5	173.0	195.0	+22.0	533.0	36.0	37.0	1.0	s.f.-d.c.
	Mean	172.2	195.0	+22.8	533.0	35.5	36.7	1.2	
17	1	174.0	167.0	7.0	278.0	35.5	37.0	1.5	d.f.-s.c.
	2	173.0	167.0	6.0	277.0	35.0	36.0	1.0	d.f.-s.c.
	3	176.0	167.0	9.0	278.0	36.0	37.5	1.5	d.f.-s.c.
	4	173.0	167.0	6.0	278.0	35.0	36.5	1.5	d.f.-s.c.
	5	173.0	167.0	6.0	278.0	36.0	37.5	1.5	d.f.-s.c.
	Mean	173.8	167.0	6.8	278.0	35.5	36.9	1.4	
18	1	174.0	111.0	63.0	50.0	35.5	37.0	1.5	s.f.-s.c.
	2	173.0	110.0	63.0	45.0	35.0	36.0	1.0	d.f.-s.c.
	3	176.0	106.0	70.0	40.0	36.0	38.0	2.0	s. cooked
	4	173.0	113.0	60.0	35.0	35.0	36.5	1.5	d.f.-s.c.
	5	173.0	114.0	59.0	35.0	36.0	37.5	1.5	s.f.-s.c.
	Mean	173.8	110.8	63.0	41.0	35.5	37.0	1.5	

s.f. - slight feed
d.f. - definite feed
s.c. - slight cooked
d.c. - definite cooked
p.c. - pronounced cooked

Table 21. Improvement in the flavor score of alfalfa flavored milk preheated to 140 °F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
1	1	140.0	120.0	20.0	533.0	35.0	37.0	2.0	d. feed
	2	141.0	124.0	17.0	533.0	35.0	37.0	2.0	d. feed
	3	141.0	125.0	16.0	533.0	35.0	36.5	1.5	d. feed
	4	141.0	125.0	16.0	533.0	36.0	38.0	2.0	s. feed
	5	140.0	122.0	18.0	533.0	36.0	37.5	1.5	s. feed
	Mean	140.6	123.2	17.4	533.0	35.4	37.2	1.8	
2	1	140.0	109.0	31.0	278.0	35.0	36.5	1.5	d. feed
	2	141.0	110.0	31.0	278.0	35.0	37.0	2.0	d. feed
	3	140.0	110.0	30.0	278.0	35.0	36.5	1.5	d. feed
	4	141.0	108.0	33.0	278.0	36.0	37.5	1.5	d. feed
	5	140.0	105.0	35.0	278.0	36.0	37.5	1.5	d. feed
	Mean	140.4	108.4	32.0	278.0	35.4	37.0	1.6	
3	1	142.0	75.0	67.0	23.0	35.0	36.5	1.5	d. feed
	2	140.0	70.0	70.0	20.0	35.0	36.5	1.5	d. feed
	3	139.0	75.0	64.0	24.0	35.0	37.0	2.0	d. feed
	4	141.0	75.0	66.0	24.0	36.0	37.5	1.5	d. feed
	5	141.0	70.0	71.0	24.0	36.0	37.5	1.5	d. feed
	Mean	140.6	73.0	67.6	23.0	35.4	37.0	1.6	

s. - slight
d. - definite

Table 22. Improvement in the flavor score of alfalfa flavored milk preheated to 160°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
4	1	160.0	136.0	24.0	533.0	35.0	37.5	2.5	s. feed
	2	160.0	134.0	26.0	533.0	35.0	37.5	2.5	s. feed
	3	160.0	134.0	26.0	533.0	35.0	37.5	2.5	s. feed
	4	159.0	132.0	27.0	533.0	36.0	38.0	2.0	s. feed
	5	161.0	132.0	29.0	533.0	36.0	38.0	2.0	s. feed
	Mean	160.0	133.6	26.4	533.0	35.4	37.7	2.3	
5	1	160.0	123.0	37.0	278.0	35.0	37.5	2.5	s. feed
	2	160.0	118.0	42.0	278.0	35.0	38.0	3.0	s. feed
	3	160.0	118.0	42.0	278.0	35.0	37.5	2.5	s. feed
	4	161.0	122.0	39.0	278.0	36.0	38.0	2.0	s. feed
	5	162.0	123.0	39.0	278.0	36.0	38.0	2.0	s. feed
	Mean	160.2	120.8	39.4	278.0	35.4	37.8	2.4	
6	1	157.0	70.0	87.0	25.0	35.0	37.5	2.5	s. feed
	2	159.0	74.0	85.0	25.0	35.0	37.5	2.5	s. feed
	3	158.0	75.0	84.0	25.0	35.0	37.5	2.5	s. feed
	4	160.0	75.0	85.0	25.0	36.0	38.0	2.0	s. feed
	5	160.0	75.0	85.0	25.0	36.0	38.0	2.0	s. feed
	Mean	158.8	73.6	85.2	25.0	35.4	37.7	2.3	

s. - slight

Table 23. Improvement in the flavor score of alfalfa flavored milk preheated to 174°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
7	1	173.0	136.0	37.0	533.0	35.0	37.0	2.0	s. cooked
	2	173.0	134.0	39.0	533.0	35.0	37.5	2.5	s. cooked
	3	173.0	128.0	45.0	533.0	35.0	38.0	3.0	s. cooked
	4	174.0	131.0	43.0	533.0	36.0	38.0	2.0	s. cooked
	5	174.0	130.0	44.0	533.0	36.0	37.5	1.5	s. cooked
	Mean	173.4	131.8	41.6	533.0	35.4	37.6	2.2	
8	1	173.0	113.0	60.0	278.0	35.0	37.0	2.0	d. feed
	2	173.0	113.0	60.0	278.0	35.0	37.5	2.5	s. feed
	3	173.0	108.0	75.0	278.0	35.0	37.5	2.5	s. feed
	4	176.0	111.0	65.0	278.0	36.0	38.5	2.5	s. feed
	5	174.0	113.0	61.0	278.0	36.0	38.0	2.0	s. feed
	Mean	173.8	111.6	62.2	278.0	35.4	37.7	2.3	
9	1	173.0	77.0	96.0	25.0	35.0	37.5	2.5	s. feed
	2	172.0	80.0	92.0	26.0	35.0	38.0	3.0	s. feed
	3	172.0	77.0	95.0	25.0	35.0	38.0	3.0	v. s. feed
	4	175.0	77.0	98.0	25.0	36.0	38.5	2.5	v. s. feed
	5	174.0	77.0	97.0	25.0	36.0	38.0	2.0	s. feed
	Mean	173.2	77.6	95.6	25.0	35.4	38.0	2.6	

s. - slight
v.s. - very slight
d. - definite

Table 24. Improvement in the flavor score of alfalfa flavored milk preheated to 140°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
10	1	141.0	196.0	+55.0	533.0	35.0	38.0	3.0	s. feed
	2	141.0	197.0	+56.0	533.0	35.0	37.5	2.5	s. feed
	3	140.0	194.0	+54.0	533.0	35.0	37.5	2.5	s. feed
	4	140.0	195.0	+55.0	533.0	36.0	38.5	2.5	v.s. feed
	5	140.0	196.0	+56.0	533.0	36.0	38.0	2.0	s. feed
	Mean	140.4	195.6	+55.2	533.0	35.4	37.9	2.5	
11	1	140.0	164.0	+24.0	278.0	35.0	38.0	3.0	s. feed
	2	141.0	169.0	+28.0	278.0	35.0	37.5	2.5	s. feed
	3	141.0	167.0	+26.0	278.0	35.0	37.5	2.5	s. feed
	4	140.0	167.0	+27.0	278.0	36.0	38.0	2.0	s. feed
	5	140.0	164.0	+24.0	278.0	36.0	38.0	2.0	s. feed
	Mean	140.4	166.2	+25.8	278.0	35.4	37.8	2.4	
12	1	140.0	104.0	36.0	30.0	35.0	37.0	2.0	d. feed
	2	140.0	100.0	40.0	25.0	35.0	37.5	2.5	d. feed
	3	140.0	107.0	33.0	30.0	35.0	37.5	2.5	d. feed
	4	141.0	108.0	33.0	30.0	36.0	38.0	2.0	s. feed
	5	140.0	110.0	30.0	28.0	36.0	38.0	2.0	s. feed
	Mean	140.2	105.8	34.4	28.6	35.4	37.6	2.2	

s. - slight
v. s.- very slight
d. - definite

Table 25. Improvement in the flavor score of alfalfa flavored milk preheated to 160°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
13	1	160.0	196.0	+36.0	533.0	35.0	37.5	2.5	d. feed
	2	160.0	196.0	+36.0	533.0	35.0	37.5	2.5	d. feed
	3	160.0	195.0	+35.0	533.0	35.0	38.0	3.0	s. feed
	4	161.0	195.0	+34.0	533.0	36.0	38.0	2.0	s. feed
	5	160.0	195.0	+35.0	533.0	36.0	39.0	3.0	flat
	Mean	160.2	195.4	+35.2	533.0	35.4	37.9	2.5	
14	1	159.0	167.0	+ 8.0	278.0	35.0	37.0	2.0	d. feed
	2	160.0	167.0	+ 7.0	278.0	35.0	37.0	2.0	d. feed
	3	160.0	169.0	+ 7.0	278.0	35.0	38.0	3.0	s. feed
	4	161.0	169.0	+ 8.0	278.0	36.0	38.0	2.0	s. feed
	5	160.0	164.0	+ 4.0	278.0	36.0	39.0	3.0	flat
	Mean	160.0	166.8	+ 6.8	278.0	35.4	37.8	2.4	
15	1	157.0	100.0	57.0	25.0	35.0	37.5	2.5	d. feed
	2	157.0	101.0	56.0	25.0	35.0	38.0	3.0	s. feed
	3	160.0	108.0	51.0	30.0	35.0	38.0	3.0	s. feed
	4	161.0	110.0	51.0	30.0	36.0	38.5	2.5	s. feed
	5	160.0	100.0	60.0	25.0	36.0	38.5	2.5	s. feed
	Mean	159.0	103.8	55.2	26.6	35.4	38.1	2.7	

s. - slight
d. - definite

Table 26. Improvement in the flavor score of alfalfa flavored milk preheated to 174°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk°F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
16	1	174.0	196.0	+24.0	533.0	35.0	37.5	2.5	s.f.-s.c.
	2	175.0	197.0	+22.0	533.0	35.0	37.5	2.5	s.f.-s.c.
	3	175.0	195.0	+20.0	533.0	35.0	37.0	2.0	s.f.-d.c.
	4	175.0	195.0	+20.0	533.0	36.0	38.5	2.5	s. feed
	5	175.0	194.0	+19.0	533.0	36.0	38.0	2.0	s.f.-s.c.
	Mean	174.8	195.4	+20.6	533.0	35.4	37.7	2.3	
17	1	173.0	164.0	9.0	278.0	35.0	38.5	3.5	s. feed
	2	175.0	159.0	6.0	278.0	35.0	38.0	3.0	s. feed
	3	175.0	167.0	8.0	278.0	35.0	38.5	3.5	s. feed
	4	175.0	168.0	8.0	278.0	36.0	38.0	2.0	s. feed
	5	175.0	164.0	9.0	278.0	36.0	38.0	2.0	s. feed
	Mean	174.6	164.4	8.0	278.0	35.4	38.2	2.8	
18	1	173.0	100.0	73.0	30.0	35.0	37.5	2.5	d. feed
	2	174.0	106.0	68.0	35.0	35.0	38.0	3.0	s. feed
	3	175.0	106.0	69.0	25.0	35.0	38.5	3.5	s. feed
	4	175.0	107.0	68.0	25.0	36.0	39.0	3.0	s. feed
	5	175.0	100.0	75.0	25.0	36.0	39.0	3.0	flat
	Mean	174.4	103.8	70.6	26.0	35.4	38.4	3.0	

s. - slight
d. - definite
s.f. - slight feed
s.c. - slight cooked
d.c. - definite cooked

Table 27. Improvement in the flavor score of rye flavored milk preheated to 140°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
1	1	141.0	123.0	18.0	533.0	36.0	38.0	2.0	s. feed
	2	140.0	125.0	15.0	533.0	36.0	38.0	2.0	s. feed
	3	142.0	122.0	20.0	533.0	35.0	36.5	1.5	d. feed
	4	138.0	120.0	18.0	533.0	35.0	37.0	2.0	d. feed
	5	141.0	122.0	19.0	533.0	35.5	37.0	1.5	d. feed
	Mean	140.4	122.4	18.0	533.0	35.5	37.3	1.8	
2	1	142.0	119.0	23.0	268.0	36.0	38.0	2.0	s. feed
	2	141.0	120.0	21.0	278.0	36.0	37.5	1.5	s. feed
	3	140.0	110.0	30.0	275.0	35.0	36.5	1.5	d. feed
	4	138.0	110.0	28.0	278.0	35.0	37.0	2.0	d. feed
	5	141.0	105.0	36.0	270.0	35.5	27.0	1.5	d. feed
	Mean	140.4	112.8	27.6	273.8	35.5	37.2	1.7	
3	1	140.0	75.0	65.0	18.0	36.0	38.0	2.0	s. feed
	2	139.0	70.0	69.0	18.0	36.0	38.0	2.0	s. feed
	3	140.0	75.0	65.0	25.0	35.0	36.5	1.5	d. feed
	4	140.0	75.0	65.0	25.0	35.0	37.0	2.0	d. feed
	5	140.0	73.0	68.0	20.0	35.5	37.0	1.5	d. feed
	Mean	140.0	73.6	66.4	21.2	35.5	37.3	1.8	

s. - slight
d. - definite

Table 28. Improvement in the flavor score of rye flavored milk preheated to 160°F. and subjected to three different vacuums without steam injection.

		Temperature milk °F.			Reduced	Milk score			Flavor
Trial	Lot	Inlet	Outlet	Difference	pressure mm. Hg.	Initial	Treated	Difference	treated milk
4	1	161.0	128.0	33.0	533.0	36.0	38.0	2.0	s. feed
	2	160.0	125.0	35.0	533.0	36.0	38.0	2.0	s. feed
	3	162.0	127.0	35.0	533.0	35.0	37.5	2.5	d. feed
	4	162.0	130.0	32.0	533.0	35.0	37.5	2.5	d. feed
	5	158.0	128.0	30.0	533.0	35.5	37.5	2.0	d. feed
	Mean	160.6	127.6	33.0	533.0	35.5	37.7	2.2	
5	1	161.0	113.0	48.0	278.0	36.0	38.5	2.5	s. feed
	2	160.0	115.0	45.0	278.0	36.0	38.0	2.0	s. feed
	3	160.0	120.0	40.0	278.0	35.0	37.5	2.5	d. feed
	4	159.0	122.0	37.0	278.0	35.0	38.0	3.0	s. feed
	5	160.0	112.0	48.0	278.0	35.5	37.5	2.0	s. feed
	Mean	160.0	116.4	43.6	278.0	35.5	37.9	2.4	
6	1	158.0	73.0	85.0	18.0	36.0	38.0	2.0	s. feed
	2	160.0	70.0	90.0	25.0	36.0	38.0	2.0	s. feed
	3	160.0	75.0	85.0	20.0	35.0	37.0	2.0	d. feed
	4	161.0	77.0	84.0	25.0	35.0	38.0	3.0	s. feed
	5	159.0	77.0	82.0	25.0	35.5	37.5	2.0	s. feed
	Mean	159.6	74.4	85.2	22.6	35.5	37.7	2.2	

s. - slight
d. -- definite

Table 29. Improvement in the flavor score of rye flavored milk preheated to 174°F. and subjected to three different vacuums without steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
7	1	174.0	158.0	16.0	530.0	36.0	38.0	2.0	s. feed
	2	173.0	158.0	15.0	533.0	36.0	37.5	1.5	d. cook
	3	177.0	156.0	21.0	530.0	35.0	37.0	2.0	d. cook
	4	176.0	157.0	19.0	533.0	35.0	37.5	2.5	d. cook
	5	172.0	155.0	17.0	533.0	35.5	37.0	1.5	d. cook
	Mean	174.4	156.8	17.6	533.0	35.5	37.4	1.9	
8	1	176.0	131.0	45.0	278.0	36.0	38.0	2.0	s. feed
	2	174.0	140.0	34.0	280.0	36.0	38.0	2.0	s.f.-s.c.
	3	177.0	136.0	41.0	282.0	35.0	38.0	3.0	s. feed
	4	176.0	135.0	41.0	278.0	35.0	38.0	3.0	s. feed
	5	172.0	133.0	39.0	278.0	35.5	37.5	2.0	s. feed
	Mean	175.0	135.0	40.0	279.2	35.5	37.9	2.4	
9	1	176.0	77.0	99.0	18.0	36.0	38.5	2.5	s. feed
	2	174.0	80.0	94.0	20.0	36.0	38.5	2.5	s. feed
	3	176.0	77.0	99.0	20.0	35.0	38.0	3.0	s. feed
	4	177.0	84.0	93.0	20.0	35.0	38.0	3.0	s. feed
	5	177.0	75.0	97.0	20.0	35.5	37.5	2.0	s. feed
	Mean	175.0	78.6	96.4	19.6	35.5	38.1	2.6	

s. - slight
d. - definite
p. - pronounced
s.f. - slight feed
s.c. - slight cook

Table 30. Improvement in the flavor score of rye flavored milk preheated to 140°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Temperature milk °F. Outlet	Temperature milk °F. Difference	Reduced pressure mm. Hg.	Milk score Initial	Milk score Treated	Milk score Difference	Flavor treated milk
10	1	143.0	194.0	+51.0	533.0	36.0	38.5	2.5	s. feed
	2	141.0	194.0	+53.0	533.0	36.0	38.5	2.5	s. feed
	3	140.0	196.0	+56.0	533.0	35.0	38.5	3.5	s. cooked
	4	141.0	192.0	+51.0	533.0	35.0	39.0	4.0	flat
	5	140.0	196.0	+56.0	530.0	35.5	38.5	3.0	flat
	Mean	141.0	194.4	+53.4	532.0	35.5	38.6	3.1	
11	1	140.0	160.0	+20.0	278.0	36.0	39.0	3.0	flat
	2	139.0	164.0	+25.0	278.0	36.0	38.5	2.5	s. feed
	3	142.0	167.0	+25.0	278.0	35.0	38.0	3.0	s. feed
	4	141.0	167.0	+26.0	278.0	35.0	38.0	3.0	s. feed
	5	140.0	167.0	+27.0	278.0	35.5	38.5	3.0	s. feed
	Mean	140.4	165.0	+24.6	278.0	35.5	38.4	2.9	
12	1	141.0	106.0	35.0	25.0	36.0	38.5	2.5	s. feed
	2	140.0	100.0	40.0	25.0	36.0	38.5	2.5	s. feed
	3	140.0	105.0	35.0	20.0	35.0	38.0	3.0	s. feed
	4	140.0	100.0	40.0	20.0	35.0	38.5	3.5	flat
	5	140.0	100.0	40.0	20.0	35.5	38.0	2.5	s. feed
	Mean	140.2	104.2	36.0	22.0	35.5	38.3	2.8	

s. - slight

Table 31. Improvement in the flavor score of rye flavored milk preheated to 160°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
13	1	160.0	193.0	+33.0	533.0	36.0	38.5	2.5	s. feed
	2	158.0	196.0	+38.0	533.0	36.0	38.5	2.5	s. feed
	3	159.0	197.0	+38.0	533.0	35.0	38.0	3.0	s.f. - s.c.
	4	161.0	196.0	+35.0	533.0	35.0	38.0	3.0	s. cooked
	5	160.0	194.0	+34.0	533.0	35.5	38.0	2.5	s. cooked
	Mean	159.6	195.2	+35.6	533.0	35.5	38.2	2.7	
14	1	159.0	167.0	+ 8.0	278.0	36.0	39.0	3.0	flat
	2	162.0	165.0	+ 3.0	278.0	36.0	39.0	3.0	flat
	3	158.0	165.0	+ 7.0	278.0	35.0	39.0	4.0	flat
	4	159.0	167.0	+ 8.0	278.0	35.0	38.0	3.0	s. feed
	5	160.0	165.0	+ 5.0	278.0	35.5	39.0	3.5	s. feed
	Mean	159.6	165.8	+ 6.2	278.0	35.5	38.8	3.3	
15	1	160.0	102.0	58.0	25.0	36.0	38.5	2.5	s. feed
	2	160.0	105.0	55.0	25.0	36.0	39.0	3.0	s. feed
	3	158.0	104.0	54.0	25.0	35.0	38.5	3.5	s. feed
	4	158.0	102.0	56.0	22.0	35.0	38.5	3.5	s. feed
	5	160.0	107.0	53.0	20.0	35.5	38.5	3.0	s. feed
	Mean	159.2	104.0	55.2	23.4	35.5	38.6	3.1	

s. - slight
s. f.- slight feed
s. c.- slight cooked

Table 32. Improvement in the flavor score of rye flavored milk preheated to 174°F. and subjected to three different vacuums with steam injection.

Trial	Lot	Temperature milk °F. Inlet	Outlet	Difference	Reduced pressure mm. Hg.	Milk score Initial	Treated	Difference	Flavor treated milk
16	1	174.0	196.0	+22.0	533.0	36.0	38.0	2.0	s. feed
	2	174.0	196.0	+22.0	533.0	36.0	38.0	2.0	s.f.-s.c.
	3	176.0	194.0	+18.0	533.0	35.0	37.5	2.5	d. cooked
	4	172.0	194.0	+22.0	533.0	35.0	38.0	3.0	d. cooked
	5	172.0	197.0	+25.0	533.0	35.5	38.0	2.5	d. cooked
	Mean	173.6	195.4	+21.8	533.0	35.5	37.9	2.4	
17	1	174.0	165.0	9.0	275.0	36.0	39.0	3.0	s. cooked
	2	176.0	167.0	9.0	278.0	36.0	38.5	2.5	s. cooked
	3	176.0	166.0	10.0	278.0	35.0	38.0	3.0	s. cooked
	4	172.0	165.0	7.0	278.0	35.0	38.0	3.0	s. cooked
	5	170.0	160.0	10.0	278.0	35.5	38.5	3.0	s. cooked
	Mean	173.6	164.6	9.0	277.4	35.5	38.4	2.9	
18	1	176.0	104.0	72.0	22.0	36.0	39.0	3.0	flat
	2	174.0	105.0	69.0	25.0	36.0	38.5	2.5	s. feed
	3	172.0	100.0	72.0	25.0	35.0	38.0	3.0	s. cooked
	4	175.0	104.0	71.0	25.0	35.0	38.5	3.5	flat
	5	170.0	104.0	66.0	25.0	35.5	38.5	3.0	s. feed
	Mean	173.4	103.4	70.0	24.4	35.5	38.5	3.0	

s. - slight
d. - definite
s. f. - slight feed
s. c. - slight cooked

Table 33. Summary of the analysis of variance for treatments with silage flavored milk.[1]

Source of variation	Degrees of freedom	Mean square	F	Significance
Subclass	17	0.601	------	------------
Steam	1	0.100	0.694	n.s.
Vacuum	2	0.436	3.030	(.05 P .10)
Temperature	2	3.011	20.910	***
S x V	2	0.209	1.451	n.s.
S x T	2	0.300	2.083	n.s.
V x T	4	0.370	2.569	(.05 P .10)
S x V x T	4	0.183	1.271	n.s.
Within	72	0.144	-----	------------

[1] Compiled from calculation of analysis of variance.
n.s. - not significant.
*** - P 0.001.

Table 34. Summary of the analysis of variance for treatments with alfalfa flavored milk.[1]

Source of variation	Degrees of freedom	Mean square	F	Significance
Subclass	17	0.687	------	-----------
Steam	1	3.803	23.05	***
Vacuum	2	0.136	0.82	n.s.
Temperature	2	2.253	13.65	***
S x V	2	0.036	0.22	n.s.
S x T	2	0.502	3.04	(.05 P .10)
V x T	4	0.407	2.47	(.05 P .10)
S x V x T	4	0.099	0.60	n.s.
Within	72	0.165	-----	-----------

[1] Compiled from calculation of analysis of variance.
n.s. - not significant.
*** - P 0.001.

Table 35. Summary of the analysis of variance for treatments with rye flavored milk.[1]

Source of variation	Degrees of freedom	Mean square	F	Significance
Subclass	17	1.246	----	-----------
Steam	1	14.003	91.64	***
Vacuum	2	0.603	3.95	*
Temperature	2	0.744	4.87	*
S x V	2	0.003	0.02	n.s.
S x T	2	1.011	6.62	**
V x T	4	0.490	3.21	*
S x V x T	4	0.124	0.81	n.s.
Within	72	0.153	----	-----------

[1] Compiled from calculation of analysis of variance.
n.s. - not significant.
* - P 0.05.
** - P 0.01.
*** - P 0.001.

Table 36. Boiling points of water under reduced pressure.[1]

Reduced pressure in. Hg	Reduced pressure mm. Hg	Applied vacuum in. Hg	Applied vacuum mm. Hg	Boiling point water °F.
22.0	559.0	8.0	201.0	197.0
21.0	533.0	9.0	227.0	195.0
20.0	508.0	10.0	252.0	193.0
12.0	304.0	18.0	456.0	170.0
11.0	278.0	19.0	482.0	166.0
10.0	252.0	20.0	508.0	162.0
2.0	50.0	28.0	710.0	101.0
1.5	37.0	28.5	723.0	92.0
1.0	25.0	29.0	735.0	80.0
0.5	12.0	29.5	748.0	60.0

[1] Data taken from McDowall's Buttermakers' Manual.

EFFECTIVENESS OF VARIOUS VACUUM, TEMPERATURE, AND STEAM TREATMENTS IN REDUCING FEED FLAVORS IN MILK

by

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A considerable amount of equipment has been installed in dairy plants in recent years to volatilize and remove off-flavors from milk. This equipment consists principally of either one or more vacuum chambers in which milk may be atomized. The principle of such equipment is the atomization of milk into a vacuum in order that the off-flavor substances will be volatilized and removed by the vacuum. Some equipment is designed to permit injection of steam for use as an entraining agent to aid volatization and removal of the off-flavor substances. Little research has been done on the factors affecting removal of off-flavors from milk by this equipment. Theoretically, preheat temperature, vacuum, and steam injection are of major importance to the amount of off-flavor removed.

The purposes of this study were: 1) to determine the effects of various preheat temperatures on removing specific feed off-flavors from milk, 2) to determine the effects of various degrees of vacuum on removal of specific feed off-flavors, and 3) to determine the effect of injecting steam counter-currently to the flow of milk on removal of specific feed off-flavors.

This study was designed to study the effects of each variable preheat temperature, vacuum, and steam injection by employing an equal number of all possible combinations of the above factors. This design will permit the observation of the effects of each factor while at the same time observing the effect of various combinations of the factors. Plant equipment was unavailable at the start of this study; therefore, a laboratory apparatus was designed and constructed from Pyrex glass to simulate plant equipment for use in this study.

Three off-flavored milks were subjected to three preheat temperatures of 140°, 160°, and 174°F. Milk heated to each preheat temperature was subjected to each of three degrees of vacuum 9, 19, and 29 inches of mercury which resulted in nine trials. Steam from a source other than the milk was injected into these nine combinations of preheat temperature and vacuum. Next milk was treated with the same combinations of preheat temperature and vacuum without steam injection, consequently a total of 18 trials was processed for each set. Five complete sets of combinations were required to provide sufficient data for statistical analysis. This required the processing of 90 lots of milk for each off-flavor studied or a total of 270 lots for the entire experiment. The effectiveness of the treatment was measured by using the difference in numerical flavor score given by a panel of four judges to the treated and untreated milk. The analysis of variance was used to determine significant differences between treatments. Duncan's Multiple Range Test was used to determine which factor within a treatment was significantly more effective.

The first feed off-flavor studied was that obtained when cows have been fed silage previous to milking. It was concluded that the 140°F. preheat temperature was more effective in reducing the intensity of that particular flavor in milk than the other preheat temperatures studied. The results indicate that the 19 inch vacuum was more effective than the 9 or 29 inch vacuum treatments. It was concluded that injection of steam did not improve the flavor score significantly than the treatments without steam injection on silage flavored milk. The optimum combination of variables studied was the 140°F. preheat temperature with either 9 or 19 inches of applied vacuum for removing silage off-flavor from milk.

The second off-flavor studied was that found in milk when the cows have been fed a considerable amount of alfalfa hay. It was concluded that the 174°F. preheat temperature was the most effective in reducing alfalfa off-flavor; however, it was not significantly more effective than the 160°F. temperature. The results revealed no significant difference between the various vacuums employed with alfalfa off-flavored milk. All the vacuum treatments improved the flavor score of the milk. The use of injected steam definitely aided the removal of the alfalfa off-flavor from milk as revealed by this study. It was concluded that there were two optimum combinations of factors for removing an alfalfa off-flavor. The optimum combination of preheat temperature and vacuum was 174°F. with 29 inches of vacuum. The most desirable combination of preheat temperature and the use of steam or no steam was 174°F. with steam injection.

The third off-flavor studied was that found in milk when the cows had been pastured on rye. This type of flavor is frequently observed in Kansas during early spring. The results of this study indicate that the 160°F. preheat temperature improved the flavor score more than the other preheat temperatures studied. The 19 inch degree of vacuum was found to be the most effective vacuum studied; however, it was not significantly more effective than the 29 inch vacuum. Using steam produced from an outside source and injecting it into the rye flavored milk showed that it definitely aided the removal of the tainting substance. The optimum combinations for removing rye off-flavor from milk were: 160°F. preheat temperature with 19 inches of vacuum, and 160°F. preheat temperature with steam injection.

It must be noted that these conclusions represent the results obtained by processing the off-flavored milk in a laboratory apparatus. Future work should be undertaken to qualify this data for plant equipment by doing research with pilot plant or actual plant equipment. The results of steam injection with alfalfa and rye off-flavors in this experiment substantiate previous work published on the increased reduction of off-flavor substances by using steam injection.

No references could be found studying the effects of various preheat temperatures or vacuums on off-flavor removal.

This study has only introduced some of the many possibilities of future milk flavor research. Some of these possibilities are the study of removing additional off-flavors from milk, study of various methods of steam injection (con-current vs. counter-current), study of varying the design of equipment (use of several vacuum chambers for multiple stage deodorization), and the isolation, purification, and identification of the actual chemical compounds responsible for the specific off-flavors in milk.