AN ABSTRACT OF THE THESIS OF

Edmond Harvey Wood for the M. S. in Food Technology
(Name) (Degree) (Major)

Date thesis is presented Apr 13, 1954

Title METHODS OF EVALUATING QUALITY OF MARSHALL STRAWBERRIES FOR MANUFACTURE

Abstract approved Redacted for privacy
(Major Professor) Pro Tem.

The need to replace the present methods of rating the acceptability of a manufacturer's lot of strawberries is indicated. Work has been done towards adapting and developing laboratory techniques for this purpose.

The quality factors checked upon were the state of maturity, the effectiveness of processing work, and the freedom from adulteration. In connection with the maturity of the strawberries a color technique is outlined, some factors of the growing conditions are introduced, and a relationship is shown between these and the aroma.

The residues of dirt and insects are checked against a classification of the processing plants in showing the quality of preparation. Mold and included water are considered under adulteration.

New methods are outlined for preparing the sample, counting the insects, estimating dirt, and evaluating maturity by color.

METHODS OF EVALUATING QUALITY OF MARSHALL STRAWBERRIES FOR MANUFACTURE

by

EDMOND HARVEY WOOD

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1954

APPROVED:

Professor of Food Technology

In Charge of Major, Pro Tem.,

Head of Department of Food Technology

Chairman of School Graduate Committee

Dean of Graduate School

Date thesis is presented Apr. 13, 1954

Typed by Marlene Collins

ACKNOWLEDGMENT

The author is grateful for the generous help and unfailing good-nature of Dr. Thomas B. Niven, Major Professor, and for the cooperation of Jayantilal H. Shah and Ka-Teng Yao, contemporary workers on the same material, for their help in laboratory preparation and analysis.

Sincere thanks are extended to Dr. Oliver J. Worthington for his criticisms and comments upon this manuscript under preparation.

Thanks are tendered to the berry processing factories visited, collectively or individually, from which the samples were obtained.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF THE LITERATURE	4
Chemical Analyses	4
Physical Analyses	9
Mold Count	13
PROCEDURES	15
Subjective Evaluation	16
Evaluation of Processing Plants	17
The 10 point System of Grading Berries for Manufacture Developed by the Author	18
Soluble Solids and pH	19
Extraction of Color	20
Insect and Sediment Count	22
RESULTS	27
Effects of Weather	27
Factors Concerned with Processing: WASHING	29
Factors Concerned with Processing: INSECTS	31
Factors Concerned with Processing: MOLD	31
Influence of Appearance on Grading	35
Production and Marketing Administration Type Rating	36
Subjective Color and Transmittance	42
Subjective Color and Aroma	46
Viscosity	49
Soluble Solids and Percent Transmittance	49
Excess Water and Softness	49
DISCUSSION	53
SUMMARY AND CONCLUSIONS	61
BIBLIOGRAPHY	63
APPENDIX	70

LIST OF TABLES

Page

Table 1.--The Relationship of Soluble Solids to Viscosity in Samples Noted as Seedy......... 28

2.--A Comparison of Percent Transmittance and Subjective Color Evaluation of Strawberries Darkened by Hot Weather......... 30

3.--The Effect of Days Since Rain on Mold, Sediment and Insects in Plants Considered

a. ABOVE NORMAL.......................... 32
b. NORMAL................................ 33
c. BELOW NORMAL.......................... 34

4.--Transmittance Values of Whole Strawberries Rated

a. 9 points or above..................... 37
b. Under 9 points and Over 7.5 points...... 38
c. 7.5 or less 39

5.--Comparison of PMA Type Grades with Author's Rating.................................. 40

6.--Discrepancies between Grading Systems....... 41

7.--Relationship between Color of Whole Berries and Aroma of the Puree

a. Light Color Group..................... 43
b. Intermediate Color Group.............. 44
c. Dark Color Group...................... 45

8.--The Aromas Grouped with the Color Categories.................................. 48

9.--The Soluble Solids of Strawberries Grouped as to the Viscosities of their Purees....... 50

10.--Soluble Solids and Subjective Ratings of Samples Noted as Juicy or Soft............. 52

METHODS OF EVALUATING QUALITY OF MARSHALL STRAWBERRIES FOR MANUFACTURE

INTRODUCTION

This research is an attempt to find improved methods of analysis and grading of berry products with a view to getting them accepted more readily for re-manufacture. In order to feel more assurance in the selection of the right material for the production of end-products, food manufacturers need more valid methods for the evaluation of quality.

The berries considered in this report represent the bulk of the strawberry pack put up in the Pacific Northwest in 1949. The Marshall variety was chosen because it is a variety which was grown almost exclusively at that time in this region.

At present the estimation of quality in frozen berries is based almost entirely upon the official Production and Marketing Administration (PMA) grades. These methods are speedy but they depend so much on personal judgment that they are not free from disagreement. They are based largely upon those outward physical characteristics of berries which are readily recognized by the ultimate consumer. They are far removed from evaluating the condition of the berries for a manufacturer's particular needs.

Manufacturers also like to know the stage of maturity of the frozen berries which they are buying. The PMA grading does not offer to put any measure on the state of maturity. Preserve makers try to get fruit which will stay whole and which will retain its bright color, while makers of ice cream like their colors to be darker and they do not look for wholeness.

Again the PMA grading does not indicate sogginess of the interior flesh, a factor which accompanies wet growing conditions. This sogginess is hard to sight-grade accurately in frozen berries even when they are sliced. Lack of brightness, lack of firmness, and lack of flavor are associated with sogginess and they are readily detected by the person eating such strawberries. These faults are strongly detrimental in a preserve.

Factors which the PMA does not rate at all are water dilution, dirt, minute insects, and mold. No tolerances for any of these defects have been set up, probably due to the Federal law which classifies them as adulterants and can forbid interstate shipment of any pack proved to contain any of them. Each of these four adulterants is present in every pack, one or more of them in every sample. Washing is bound to add a film of water to each berry to adulterate the pack. Dirt will always be found on products growing so close to the ground. Mud is hard to remove by mechanical means and on strawberry surfaces it usually escapes detection by an inspection crew. Tiny, almost invisible, insects which do not wash or shake off can be found in every pack of berries. Mold can also be detected in every commercial batch. Experience has shown that the greater the build-up of mold visible before processing the higher the count seen under the microscope afterwards.

The object of this paper is to indicate speedy ways of evaluating chemical and physical properties, perhaps some of the more adaptable methods for the points already mentioned, and to put numerical limits on them.

REVIEW OF THE LITERATURE

Published reports on tests and analyses of fruit products began to appear back in the nineteenth century, many of them being intended to aid in detecting fraud. Many of the early methods reported in the United States were introduced from Europe, mainly from France and Germany. These were noted in American publications mostly at the turn of the century when B. J. Howard (28, 40) and A. L. Winton (71) began evaluating and initiating tests to provide a basis for the standards which were being contemplated for foods at that time.

Chemical Analyses

Sugars have been recommended in many of the suggestions for checking quality; in the early years most workers advocated analytical determinations (11, 15, 16, 38, 48, 53). Inasmuch as the analytical methods for reducing and total sugars demand skill and considerable time from the analyst (23, 59), there has recently developed a trend towards the indirect methods such as specific gravity, as advocated by Hinton and Macara (24) and the use of the refractometer by Jessep (31). Willberg (67) ignored the sugar determination in his proposals, while Pien (46) does not agree that a factor as open to easy fraud as is sugar can serve as a reliable test of purity.

Schuphan (55) found that sugar in strawberries varies directly with the advance in maturity and that under the same conditions it varies inversely with total acidity. Similarly investigators discovered a direct relationship between sugar content and sunshine in contrast to cloudy weather (37, 55), and between sugar and color (7).

The work of Kimbrough (33) and Schuphan (55) and earlier workers has suggested that there is an inverse relationship between sugar and titratable acidity, but this has not been substantiated by Robinson et al. (51), and Culpepper (8). Yao (70) who was using the same material as was worked upon in this project, found a high ratio of total sugar to titratable acid. Such a wide discrepancy might be due to sampling procedures such as would occur if Schuphan and Kimbrough had obtained their material from a single growing plot and during a period when weather did not vary greatly, conditions which are the opposite to those which affected these samples. In this series of ours, soluble solids which represent the total sugar according to Yao (70) did not appear to be dependent upon maturity, nor, in general, did these readings reveal a consistent pattern with titratable acidity. Bollinger (2, 3) could not find an explanation for the variations which were occurring between coworkers who were measuring parts of the same sample.

Guillaume and Michon (15) as well as Pien (46) recognize that they must do extensive work with many supplementary analyses and over many seasons to establish reliable data on the normal composition of any fruit.

Acidity values, either total acidity or free acidity or both, have frequently been included in making up tests. Many workers (8, 11, 15, 24, 38, 51, 53, 64, 67) have suggested them in their lists of favored tests. For each of these types of acidity the official USDA tests, and those of others when based upon titration readings (3, 52), are somewhat too complicated for speed (2, 3). There is disagreement over interpreting these two acid readings with each other. Hinton and Macara (24, 38) indicated that there is a reliable relationship between them, but others have since found them not well correlated due to an unpredictable buffering effect of fruit juices (8, 45, 51). Pritzker (48), who developed a broad list of chemical tests for fruit juices, omitted any for acidity.

Alcohol content was a factor which Pritzker (48, 49) twice suggested analyzing for, but the use of this test has not appeared in British or American works, perhaps due to the delicacy of the process. Recent procedures used for this analysis again are not speedy or simplified (47).

Water as an adulterant is a frequent target for the research of European workers (16, 49, 62, 67). Where minimum values of chemical constituents are usable as a basis for detecting dilution British and French workers (15, 38, 46) achieve similar results by analyzing for insoluble solids, ash, and for the constituents of ash. Halverson (17) reviewed the methods used in this country for detecting water and showed that they are based upon this 'minimum value' principle. An ingenious chemical test (63) for water in grape products is known in France, and someday its principle might come into use here applied to other fruit products. It is based upon the theory that grape juice is saturated with tartaric acid and that any proportion of less than full saturation must represent dilution. It was first adopted in France in 1914 and was advocated for use in the United States at a later date. This principle was applied to berries in 1926 by Villiers (64) who used a citric acid determination, and by Hartmann for adulteration of grape juice (21). There is also a color check for adulteration with water, and it also depends on a principle of saturation (36).

The determination of the total ash content (15, 40, 46, 48, 53, 67) has been used as an indirect check upon dilution and adulteration. Some investigators have pointed out that the particular values for elements such as potassium, phosphorus, and calcium, which can be obtained from ash, are less subject to fraud than are most ingredients (53). Willberg (67) also wanted to have the total alkalinity known for the ash. Sale (53) has advocated, too, that total ash, K_2O, P_2O_5, and insoluble solids, taken collectively are a good criterion for the fruit content of jam. Ash readings, however, are not found in Hinton and Macara's (24) summary of methods which appeared two years later.

Still other bases for standards have been suggested. They lead one to believe that there are many ways of checking upon quality and adulteration and to suspect that some of them are the pets of their advocates. Pectic acid and lead numbers have been used by Hinton and Macara (24, 38) for tests on jam fruits. These workers had found that lead numbers correlated well with the percent of total acid. Willberg (67) has suggested nitrogen compounds. Demortier et al. (11) have used tannin determinations as well as tests for specific acids such as malic and tartaric. Alcohol insoluble solids is a time-consuming test and yet it has been advocated by Guillaume and Michon (15). All these procedures demand considerable skill and special equipment which may not be available in many commercial plants.

Some of the research workers (6, 13, 39, 56, 58) have accumulated ascorbic acid data which may give hints on the time of storage. These data are not advocated seriously by those setting up standards, though, due to the variability of readings which occur in fresh fruit during a season and from season to season as well as that caused by differences in regions (7, 18, 33, 47, 51, 55, 58).

<u>Physical Analyses</u>

Many suggestions (12, 24, 38, 43, 46, 49, 51, 53) for physical examination of fruit have been based upon the juiced, comminuted, or pureed form, and many of these ideas have been applied commercially to tomato products already.

An estimation of the total solids is frequently wanted by some workers (44, 46) but others want results only on the insoluble part of the solids (38, 40) pointing out a correlation between insoluble and total solids. Culpepper et al. (8) did not find this relation reliable, however. From an early date experimenters (63, 64) have accumulated knowledge on solids in jam and wine, and recently in tomato purees. Many methods are recommended for determining soluble solids in fruit products; by analytical procedures (11, 16, 43) and by the refractometer (5, 12, 17, 24, 31).

Talon (62), in determining the water content of fruit products, tried both analytical and physical methods. Some analysts (16, 35) have come forward with methods of their own for finding the soluble solids, usually involving much detailed technique. Talon has reviewed many of these methods, especially the procedures for removing water. He tried different ways of evaporating water, such as using vacuum and H_2SO_4, and then compared his analytical results with the readings obtained from the refractometer. He found that he could infer and project the amount of total solids from such readings. Horner (27) reviewed methods for determining the total solids of a tomato puree by direct evaporation, distillation, chemical drying and physical properties. He discarded all such ways as inaccurate and cumbersome and finally concluded, "In view of the wide variation in the results obtained by different methods, a standard procedure based on the determination of refractive index is recommended." This method is now recommended by the United States Department of Agriculture on grounds of simplicity in face of the awkward drying tests (43). These were almost the same conclusions as those of Talon (62) after his series of tests on jellies.

Density as a factor in judging quality has been supported by some (11, 15) but it is objected to by Hadorn (16) on the grounds that it is not a reliable indication of soluble solids. Firmness, as measured by the penetrometer was found to run too variably within samples (6).

Recently Kamer and Jansen (32) found a speedy way to measure specific gravity of a puree by using only a column of standardized solution of non-miscible liquid and a calibrated dropping pipette. No attempt was made to follow this up in the project given here.

Consistency has apparently not been offered as a factor for grade in fruit products other than in jam (14) although it is included in the evaluation of some canned vegetables such as pumpkin and sweet corn. Instead, viscosity is the measure generally used on fruit products (15, 34). Davis (10) reports on a falling-ball measurement of viscosity to detect water in honey. Hoppler (26) points out anomalies which occur in the viscosity of a sugar-acid product under storage.

Objective methods are available for rating the color of fruit samples or for comparing different samples of the same kind of fruit (51, 57). Until recent years it has only been the lack of handy physical tools which has accounted for this measurement being by-passed. Hartman (22) used a chemical test by titrating for color along with tanin, but present equipment is non-chemical, accurate and fast. No reference has been found showing discrimination against color values except that of Pien (46), who suggested the issue of possible fraud due to adulteration. Sondheimer and Kertesz (60) have emphasized that anthocyanin pigments are responsible for much of the color in strawberries and in addition that the color intensity depends upon free acidity. They extracted the anthocyanin pigments with aqueous (60) and ethyl alcohol (61) solutions. When they examined the pigment analytically they found correlations between changes in wavelength due to deterioration such as oxidation or loss of flavor.

Much of the literature dealing with the color rating of anthocyanin in fruit has appeared in very recent years. Beattie _et al_. (4) have observed that all fruits change color and flavor in storage, the speed of the change increasing with temperature and with the accessibility of air. Shah (57) used the same samples which are reported upon in this paper as he compared ways of stating objectively the color of strawberries. Yang (69) used the spectrophotometer in an attempt to distinguish between pure fruit juices and mixtures of juices and did not have much success.

The first data on foreign material in puree printed in this country appear to be contemporary with Winton's first textbooks on food analysis, about 1900. After the manner of European analysts Winton illustrated his work with microdrawings revealing the characteristic structural features of the true product and of the likely foreign materials and adulterants. In 1907, Howard (28) commented on this as a "nearly new idea". Since that period microdetection has gradually lost favor in the United States; but it is still in good favor in France and Germany where, when chemical analysis fails, the microscope is claimed to be the only certain detector of some forms of adulteration. Right up to recent years literature has appeared in this country carrying photomicrographs of insect and vegetable structures as a means of identifying them on final analysis.

The official AOAC methods (1, pp.699-702) of determining quantities of extraneous matter and filth form the background of all the present ways of checking purees.

The Wildman method (17, 19) is the basic one for finding insect fragments. In 1932 Wildman reported upon the use of his flask technique with a gasoline separation layer in place of oil for berries and for similar fiber-containing products such as cereals and fig-paste. In 1937 Howard (29) was relying upon this principle for detecting insect fragments in tomato products. In that year Wilder and Joslyn (65) introduced a separatory funnel method to supplement the original flask, for they had found that by running the gasoline layer from a funnel directly onto a filter paper they could cut down the time of preparing a mount from 20 or 30 minutes to 5 or 10 minutes. Harrison in that year wrote about its commercial application (20).

In 1945, Hodges (25) compared several methods for insect detection in figs and decided that flotation with gasoline was the best and was superior to the official method (1, p.699) of the day. Since 1945 the Official Referee (42) has been recommending that methods for detecting extraneous matter in fruits be given collaborative studies.

Mold Count

Methods for detecting and estimating mold and micro-organisms in certain foodstuffs were well developed by Howard before 1907 (28). Here again tomato products came in for the main study. For a long time examinations contained counts on yeasts and bacteria as well as mold until a correlation was established linking the three together (9, 30, 41). Mold is taken alone in commercial practice today.

Darling (9) noted that the Howard mold counts in puree smears did not always give results comparable to those in un-mashed products due to the breaking-up of the mold clumps. He decided that a modification of the regular Howard test was needed. Needham and Fellers (41) applied the method to berries and went on to offer count figures which represented known proportions of moldy berries which had been added.

PROCEDURE

During the 1949 packing season berry plants were visited in Oregon and Washington. Conditions within the plants were noted; especially the equipment and its layout, the rate of flow of fruit over the line, and the number of employees doing inspection work. Faults were recorded such as the crowding of berries on the belt, and any spreading-out of processing time.

Notes were recorded about the weather throughout this period and remarks made on how weather had affected the field quality of the strawberries. In this way the observer tried to account for those samples which carried more mud than usual, for moldiness in some samples, and for major variations in ripeness. Most of the plants were visited frequently between the times when the samples were gathered.

A sample of about 1 lb. of strawberries was caught as it rolled off the end of the processing belt before it was sugared. Whatever water was being carried into the container was considered part of the sample. The sample box was a lidded, lily-cup type container on which was written the name of the firm, the date, and any special features known for that pack such as the size or the grade. The samples were usually cooled to 0° F. within 4 hours and were stored at this temperature.

Experimental work started on the samples when they were transferred from 0° F. storage to the 34° F. room. When the sample was removed from 34° F. storage 12 to 15 hours later it still tended to be in a frozen block and was held one hour at room temperature before being turned out into a white inspection bowl and separated.

Subjective Evaluation

The color, size, and condition of the berries were noted, and they were scored under an arbitrary 10 point system. The estimation of quality was based mainly on color and the nature of the defects, and on this account it stressed the subjective judgment of a person accustomed to evaluating berries for the preserving industry. Contamination by extraneous matter and by apparent water were recorded in the possibility that these factors would correlate with objective readings. A group of 22 samples, besides being given this numerical scale, were scored under PMA grading rules by a committee composed of a professor of grading instruction, a graduate student who was undertaking other analytical work on these samples, and the author.

As soon as they were thawed sufficiently the berries were blended in a RYP juicer which removed seeds and large pieces of extraneous matter. The mixer was taken apart after each sample was pureed and all material clinging to its sides was saved for that sample. Care was taken to give all samples the same treatment; the rate of flow and centrifugal speed (5000 r.p.m.) were constant. Each lot was stored in a covered glass tumbler and its weight was noted.

Analysis of the puree was initiated by letting the author's personal judgment check differences in the aroma, viscosity and appearance. Whenever further analysis could not be carried on right away the material was returned to storage in the 0° F. room.

Evaluation of Processing Plants

Three points were evaluated, these being Washing, Speed of Dumping, and Inspection work.

1. The washing evaluation was based upon the design and action of the washer, considering also the water flow.

2. Speed of dumping berries into the washer was judged by the unhurried motion of emptying out the flats. The berries should have room enough to get doused in the water bath without riding partly out of the water and should lie only one deep on the inspection belt afterwards.

3. Inspection was mainly gauged by the number of women per dumper--11 or 12 are considered a fair average when all are working on the same belt. The attention they give to doing a perfect job is also included in this rating. This is a matter which is partly controlled by management.

The criteria which helped to put a rating upon the washing processes were based upon an efficient berry washing machine modelled on the McLauchlan[2] design, when fed with fruit at a rate within its capacity. Such machines vary in efficiency due to modifications in design and to the rate at which flats of berries are dumped into the washer. The plants were rated 'under normal' when they had less than proper capacity in either of these two particulars as well as when they employed less than the usual number of women to serve as inspectors on the belt.

<u>The 10 point System of Grading of Berries for Manufacture Developed by the Author.</u>

The full score of 10 was given to berries which were all bright, well-colored but not darkened, firm and free from seediness, contained no obvious extraneous matter and fell within the size range of 1½" to 5/8". The score of 9 allowed slight unevenness of color, such as slight scorching on less than one half of the berries. One piece of calyx or leaf might also be found. These lots were approximately grade A according to the PMA grading system.

The score of 8 was roughly equivalent to PMA grade B. It was allowed to be somewhat lower than grade B specifications for size and seediness and for unevenness or lightness of color, but was more strict on obvious extraneous matter,

---

[2]McLauchlan washer: A power-driven cleaner into which the berries are dumped one crate-ful at a time. The berries land in water, travel under water sprays and over drainage bars before being discharged.

softness in character and general dark color.

Samples scoring 7 points and lower were rated as unacceptable for the purpose of making high quality preserves.

Soluble Solids and pH

The Brix reading was determined with a Bausch and Lomb hand refractometer soon after the puree had been prepared. When the soluble solids readings were checked the day after the puree had been put back into 0° F. storage no significant change was registered. The hand refractometer was apparently not sensitive enough to detect one if there were any. When the pH readings (taken with a Beckman pH meter) were obtained under similar conditions a change in values was apparent.

The free acidity of juices had been said not to change much in storage, and these reports led the writer to omit any re-check of the pH on the first fruit puree samples which he put into 0° F. storage overnight. That the pH readings were changing noticeably under these conditions can be inferred now from the consistent changes found in other data which are tied in with pH values. Appendix table 1 shows the actual pH values of samples of puree before and after storage for 24 hours at 35° F. and with them are listed the comparable changes in percentage transmittance of light which they gave when checked in the

Lumetron Colorimeter.

Obtaining the pH readings on the color extracts of ethyl alcohol of all the samples was an afterthought since it was thoughtlessly assumed at first that the values of pH of the raw puree would not change under the 2½ for 1 dilution caused by adding the ethyl alcohol. A third of the tests were made without getting this reading and no interpolation has been attempted to bring the values of the missing extract findings into line with known ones on the basis of their subsequent puree figures. The H^+ ion concentrations of the alcohol extracts were determined just before running the Lumetron tests. Whenever these extracts were stored at 0° F. overnight the pH and allied values, when re-checked, were found to have changed noticeably.

Extraction of Color

In order to prepare a base for measuring the light transmittance of samples, 10 g of puree were weighed into a 50 ml. beaker and then an alcohol extraction was made by stirring in 25 ml. of 95% ethyl alcohol. A minimum of 10 minutes in the alcohol was allowed for the extraction of the anthocyanin pigments. By then the pulp was tinged only a faint yellow. The material was then filtered through coarse filter paper into a calibrated test tube. Since the liquid which first came through the paper was sometimes uncolored all test tubes were shaken up before any readings were taken in the Lumetron instrument.

The blue-green filter which had a principal wave length of 490 milli-microns was used in the Lumetron. The percent transmittance of light passing through the extract was measured on the Lumetron dial after its needle had been set for 100% transmittance with a standard blank (distilled water). In addition, the 530 filter was tried, since Kertesz (60) had found a peak maximum intensity between these two wave lengths when testing anthocyanin pigments extracted from strawberries both by water and by ethanol. The readings obtained from the 530 filter proved to form a pattern similar to that made by those from the 490. These data are to be found in Appendix Table 2.

The time intervals allowed between making the puree and adding the alchol for extraction were not standardized. Also those times between the alcohol extraction and the start of filtering were not regulated, nor were the times for which the filtered extracts were kept before taking their readings in the Lumetron. This was in spite of the warning on this point given by Kertesz (61) who claimed that one hour was needed for full extraction of color. It is not known whether large differences between such intervals of time have influenced the readings of the percent transmittance to a noticeable extent. However, for the rough preliminary purposes of this investigation that would probably not be important. The pH of the ethanol itself and whatever buffering effect it may have had on the puree were not determined.

Insect and Sediment Count

A speedy and perhaps original way of extracting and counting insects was undertaken. From the start it gave results which seemed satisfactory and almost no further modifications were introduced later. For example, in the first 10 samples examined there were found 23 thrips and parts of thrips of which 10 were in the transparent and almost invisible nymph form, 1 worm of length 1 mm. and therefore normally undetectable by other methods, 1 aphid, and 96 mites (non of which would have been detectable on filter paper).

A separatory funnel, 500 ml. size, was chosen to do the task usually done in a Wildman flask. This funnel was too small and narrow for best results but it was adequate to illustrate the method. While using this equipment, a test for sediment also can be carried out with very little cost in time.

100 ml. of the puree was measured into the separatory funnel which was then filled to the top with air-free water (distilled or boiled). It was mixed together in this special way: first it was stirred with a rocking and spinning motion for 1 minute and left swirling until settled, then

swirled again gently but without rocking. When the contents had settled, approximately 20 ml. were withdrawn through the fully opened stopcock and were run evenly onto coarse filter paper over a Buchner funnel under suction. This portion contained the heaviest sediment and represented the dirt which had not been removed from the berries by the washing procedures at the processing plant.

It was necessary to resort to a microscope to detect the sediment particles on the filter paper. Sand and soil were easily distinguished--sand by the angular shape of the particles--and were recorded separately. In a rough way soil particles were graded into two sizes; namely, above 0.1 mm. as seen under the microscope, and 'specks' which are below 0.1 mm. under magnification. Any particle with size down to where it was barely visible to the naked eye was counted as above 0.1 mm. when viewed under the microscope, although by actual free measurement these smaller ones were much less than the 0.1 mm. by which they were listed. Soil particles of this size can be broken into much smaller pieces, tiny fragments which had the appearance of dust and were listed as 'specks'. A count of all these smaller ones was made unless they were very numerous. Other extraneous matter was noted, but it was scarce.

Approximately 10 ml. of light grade colorless mineral oil was transferred to the separatory funnel containing the pulp, and sufficient previously-boiled, hot water was added to fill the funnel. The mixture was shaken vigorously for two minutes to get the oil in contact with all the pulp. When the liquid had become still it was swirled gently with the least agitation at just the speed to get all the pulp to move but not to mix the layer of oil. It was allowed to settle again. To withdraw the pulp the contents were started swirling slowly so that when the stopcock was opened the floating pulp formed a vortex down to the outlet. At intervals the run-off was stopped, hot water was added down the funnel sides, and swirling was restored to the speed where the pulp moved down the middle without involving any of the oil layer. On completion little or no pulp was left under the oil.

The oil was allowed to drain into a container for viewing under the microscope. The hot water which rinsed down the inside of the funnel brought the level of liquid in the container to a convenient height for microscopic work. The container was of clear glass, rectangular, about 3 by 5½ inches inside and 2 inches deep. It contained a grid of transparent lucite supported close to the surface. The grid was made from strips ½ inch wide joined vertically to make cells of the proper size to contain one field of the microscope under low power. These fields were approximately ½ inch squares. It seemed best to add water to the dish until the oil was just below the top of this grid. In that way all the oil layer was raised within the grid framework.

The insect dish was examined under a binocular microscope at low power resting on white paper which reflected light through the bottom. The oil-floated insects and insect parts were counted by their type where it was known. Many insects which would have escaped notice on filter paper could be recognized when floating freely in oil. For example, the commonest creature to be found was the mite, a thing which is undetectable on a paper background at the magnifying power which is normal for searching for insects. The mites' legs distinguished their transparent bodies from bubbles. The nymph stage of the thrips, whose transparent body is only revealed by its eyes when lying against filter paper, is outlined completely in the liquid.

Minute gas bubbles frequently were found and they slowed down the recognition of insects. Their prevention started with de-aerating the water used in the oil flotation and wash. When bubbles were numerous in the oil under the microscope surface-active materials were mixed in, and agents such as alcohol, gasoline, and petroleum ether were tried as a means to reduce their number.

To check the efficiency of insect removal from the pulp, tailings of waste pulp from a dozen samples were collected and treated with fresh oil. An average of only one insect or insect fragment was recovered each time from

3 such batches tested. On the seed portion which was discarded from the puree-making no check was run for the amount of insects, sediment and mold which must have stayed in with it. That has been a serious omission, for unless those two separated parts show an agreement towards each other several methods which the author is advocating will have to be modified.

RESULTS

Effects of Weather

Prior to the start of sampling on May 28 the weather had been favorable for producing clean, mold-free strawberries, and they were well developed except for a number of seedy berries and "cat-faces"[3]. The seedy condition was still common enough on June 15 that one processor, who was using PMA In-plant Inspection, was not able to keep his quality in grade 'A'. The descriptions of 13 of the total 71 samples mentioned 'seediness' or were noted as having at least 3 cat-faces in a sample. The dates of harvest of these 13 samples were well spaced throughout the season. They are tabulated in Table 1.

The average Brix reading for these samples in Table 1 was 10.31 ± 1.39. In describing the viscosity of the puree of these 13, 85% were called medium or thick while among all the remaining samples those with medium or thick puree made up 73%.

There were spells of damaging hot weather which affected color in the period of June 3 to 6 and June 13 to 19. A greater-than-usual portion of the fruit coming to

---

[3]Cat-face: A firm, local area on the berry surface, somewhat shrivelled or flattened and having the appearance of undeveloped seed parts crowded together.

Table 1

The Relationship of Soluble Solids to Viscosity in Samples Noted as Seedy

Sample Number	Date Processed	Percent Soluble Solids	Subjective Viscosity Rating
42	6/2	9.50	thick
32	6/3	10.00	medium to thin
111	6/4	9.25	thick
116	6/6	8.10	medium
108	6/7	8.00	medium
105	6/9	10.25	thick
110	6/9	10.00	thick
106	6/14	10.10	medium
43	6/15	11.25	thick
114	6/16	12.20	medium
34	6/19	11.50	very thick
115	6/25	12.10	medium to thick
113	6/27	11.75	medium to thin

Average Percent Soluble Solids reading	10.31
Standard Deviation	1.39

the plants bore an over-dark appearance on the approximate dates June 4 to 9 and June 14 to 21. Fourteen out of the 23 samples which carried the description 'dark' were obtained on these dates. Their average percent transmittance in the Lumetron was 16.70 ± 3.36. These values are tabulated in Table 2.

Severe rains occurred on May 30 and June 19. For several days afterwards the berries which were received in all the plants carried more mud than before. For the 7 samples dated up to 5 days past each rain the sediment count averaged 28.3. However, for practical purposes this is identical with the average for the 44 samples checked, which was 29.0. Sufficient data has not been gathered to establish a trend.

When mold was calculated on a basis of 9 days from the rain composing a single group and the figure representing this was compared with counts taken on material gathered on the tenth day and later, the scores are 9.0% fields for those first 9 days and 4.3% fields later.

Factors concerned with processing: Washing

Washing methods in the factory were not always adequate to remove mud, and this loss in efficiency seemed to be due to one or the other of the two following causes: (1) inadequate design of the washer, and (2) overloading the washer with berries. By taking special notice of these

Table 2

A Comparison of Percent Transmittance and Subjective Color Evaluation of Strawberries Darkened by Hot Weather

Sample Number	Date	Percent Transmittance Filter 490 mμ	Subjective Color Evaluation
116	6/6	15.1	dark to medium
29	6/9	20.5	dark, some scorched
30	6/9	17.0	dk., some overripe
110	6/9	17.0	md. dk., 2 scorched
38	6/14	16.0	dk., 2 slightly scorched
41	6/14	11.0	dk., 2 or 3 scorched
106	6/14	19.1	md. dk., 3 scorched
43	6/15	12.0	md. dark to dark
112	6/15	13.0	dk., 1/3 scorched
33	6/16	18.0	dk., some scorched
103	6/16	20.0	dark
104	6/16	19.0	dark
31	6/17	14.0	dark
16	6/19	22.2	uniformly dark

Average Percent Transmittance	16.70
Standard Deviation	3.36

conditions the plants were rated as "above normal", "normal", or "below normal". When grouped in this way the berries had sediment counts which averaged 16.3, 32.1, and 44.5 respectively. These data are summarized in Tables 3a, 3b, and 3c.

Factors Concerned with Processing: INSECTS

Insect populations cannot be reduced effectively by hand operations. Mechanical devices and washers are the best means available for removing them. Their counts are listed in Tables 3a, 3b, and 3c. Insect populations counted per sample ranged from 4.6 representing the group of plants which had the best processing conditions, to 28.5 for the group of poorest processors. 7.5 was the number for the group in between. That these averages should have fallen into agreement with comparative ratings which were given to the efficiency of factories may be due simply to chance and not be affected by the differences in equipment and care. The extremely high counts were on mites, and reduction of these has not been proved to be affected by any washing processes.

Factors Concerned with Processing: MOLD

Rainy weather has a great influence on the moldiness of strawberries. About the 4th day after a rain moldy berries are likely to appear most heavily among the incoming fruit at the plants. This increase in moldiness

Table 3a

The Effect of Days Since Rain on
Mold, Sediment and Insects
in Plants Considered ABOVE NORMAL

Packer's Code	Sample Number	Date	Days Since Rain	Mold	Sediment	Insects
A	2	5/30	0	0	6	7
	21	6/16	17	4	2	none
	22	6/16	17	4	5	2
	33	6/16	17	0	--	--
	103	6/16	17	2	8	1
	104	6/16	17	4	4	none
B	5	5/31	1	10	10	10
	7	5/31	1	6	33	9
	19	6/10	11	6	70	3
	20	6/10	11	0	3	3
	30	6/9	10	2	--	--
	39	6/7	8	0	--	--
	108	6/7	8	14	6	none
	112	6/15	16	10	6	6
	121	6/10	11	2	40	4
C	9	6/11	12	10	0	9
	118	6/11	12	0	30	8
D	14	6/22	2	2	10	4
E	25	6/9	10	8	28	8
Averages				4.4	16.3	4.6
Standard Deviation				4.2	19.0	3.5

Table 3b

The Effect of Days Since Rain on
Mold, Sediment and Insects
in Plants Considered NORMAL

Packer's Code	Sample Number	Date	Days Since Rain	Mold	Sediment	Insects
F	4	5/30	0	6	20	1
	8	5/30	0	48	12	58
	106	6/14	14	8	15	7
	113	6/27	9	10	33	4
G	10	6/11	12	8	66	15
	16	6/19	0	12	30	2
	18	6/11	12	6	16	5
	34	6/19	0	10	--	--
H	11	6/3	4	0	4	1
	35	6/7	8	4	--	--
	101	6/7	8	1	26	1
	107	6/6	7	2	37	3
	119	6/3	4	10	10	7
I	15	6/21	2	4	34	none
J	24	6/16	17	2	3	4
	42	6/2	3	2	--	--
	117	6/2	3	10	120	10
K	41	6/14	15	0	--	--
	109	6/14	15	2	11	2
L	36	6/13	14	2	--	--
	37	6/1	2	0	--	--
	105	6/9	10	0	64	3
	115	6/25	6	10	67	1
	122	6/13	14	11	9	none
Averages				7.0	32.1	6.9
Standard Deviation				9.7	30.1	13.3

Table 3c

The Effect of Days Since Rain on
Mold, Sediment and Insects
in Plants Considered BELOW NORMAL

Packer's Code	Sample Number	Date	Days Since Rain	Mold	Sediment	Insects
M	3	5/28	--	6	150	3
	17	6/11	12	8	37	4
	27	6/16	16	0	--	--
	32	6/3	4	2	--	--
N	12	6/4	5	16	17	17
	111	6/4	5	6	26	5
O	13	6/21	2	32	19	16
	31	6/17	18	4	--	--
	120	6/13	14	10	9	none
P	1	5/30	0	2	3	10
	6	5/30	0	6	80	2
	23	6/1	2	2	5	250
	25	6/9	10	10	91	none
	28	6/1	2	2	--	--
	29	6/9	10	2	--	--
	38	6/14	15	2	--	--
Q	110	6/9	10	6	47	7
R	40	6/16	17	0	--	--
	114	6/16	17	10	22	5
S	102	6/6	7	10	70	3
	116	6/6	7	22	48	5
Averages				7.5	44.5	23.4
Standard Deviation				7.8	41.2	65.4

will generally continue for another 3 days or so. The length of time that the fruit is held before being frozen also governs the amount of mold formation. No consideration was given to this time factor when the author was assigning the "normal" ratings to the processors, although a large part of the evening receipts in two of the plants was usually carried over through the night to be processed on the dayshift.

Data on the mold counts are also found in Tables 3a, 3b, and 3c. Here again the averages obtained from each group fall into line with the efficiency ratings which were assigned to the factories: berries from the "above normal" factories had an average mold count of 4.4, from the "normal", 7.0, and from the "below normal", 7.5.

Influence of Appearance on Grading

The subjective grading of whole strawberries based upon color, character and extraneous matter gave scores which did not correspond to physical tests. The author's personal rating showed bias in favor of light color and freedom from extraneous matter. These factors are favored in preserve making. A leaning in this direction was expected beforehand. The conjecture that bias was likely to be involved was confirmed to some extent by the percentage of the best liked samples (those rated with 9 points or better) being shown to be 39% of the lighter colored samples against 30% best liked ones among the darker, and by the percentage of those samples which had a rating of 7 and below (which were the least favored) being only 17 for the light ones but 27 for the dark. However, for both of these categories of the author's personal grading and for that of the medium grade which came between them, the percent transmission measurements on the Lumetron averaged out almost equal to each other. These results are recorded in Table 4a, Table 4b, and Table 4c.

Production and Marketing Administration Type Rating

Of the 22 samples summarized in Table 5, 4 received "A", 9 received "B", and 9 graded "D", or substandard, when graded under PMA rules. Lack of uniformity of color was the reason why 7 out of the 9 samples which failed to make above "D" grade were disqualified. These substandard samples have been listed again in Table 6 to emphasize the differences which can accompany personal decisions. Under the author's own system of grading, which was done at the same time, one of the nine was chosen to be better than average, 4 were given the intermediate rating with points less than 9 but over 7.5, and only 4 were rated down in the same general substandard region. The basis upon which the author's evaluation was founded is partly indicated by the descriptive wording which accompanies them.

Table 4a

Transmittance Values of Whole Strawberries rated 9 points or above

Descriptive Group - Light to Medium (16 out of 41 light samples--39%)

Sample Number	Percent Transmittance	Author's Rating
3	27.0	9.5
14	24.0	9.0
21	25.2	9.0
24	19.0	9.0
25	18.9	9.0
35	19.3	9.0
36	18.0	9.0
39	30.0	9.0
42	27.0	9.0
45	31.0	9.0
48	35.0	9.0
49	31.0	9.0
101	23.0	9.0
102	23.0	9.0
118	22.0	9.0
Average	24.9	9.0
Standard Deviation	5.2	0.1

Descriptive Group - Red to Dark (9 out of the 30 dark samples--30%)

Sample Number	Percent Transmittance	Author's Rating
4	21.5	10.0
15	18.2	9.0
19	17.5	9.0
29	20.5	9.0
33	18.0	9.0
37	18.0	9.0
103	20.0	9.0
104	19.0	9.0
110	17.0	9.0
Average	18.9	9.1
Standard Deviation	1.5	0.3

Total Lumetron average	22.6	Total Author's Rating	9.1
Standard Deviation	5.1		0.2

Table 4b

Transmittance Values of Whole Strawberries
rated under 9 and over 7.5 points

Descriptive Group - Light (18 out of the 41 light samples--43%)

Sample Number	Percent Transmittance		Author's Rating
1	28.0		8.0
5	31.5		8.0
6	37.5		8.0
7	27.3		8.0
8	28.0		8.5
9	16.0		8.5
11	28.0		8.5
18	31.2		8.5
22	27.0		8.5
26	24.0		8.5
28	32.9		8.0
32	34.0		8.0
40	44.0		8.5
44	24.0		8.0
105	25.0		8.5
107	21.5		8.0
119	27.3		8.0
Average	28.7		8.2
Standard Deviation	6.4		0.3

Descriptive Group - Dark (13 out of the 30 dark samples--44%)

Sample Number	Percent Transmittance		Author's Rating
10	14.5		8.5
13	15.0		8.5
16	22.2		8.5
17	19.5		8.5
20	27.1		8.5
31	14.0		8.5
38	16.0		8.0
109	23.6		8.5
115	15.1		8.0
120	10.3		8.5
121	15.6		8.0
122	17.2		8.5
Average	17.5		8.4
Standard Deviation	4.7	Total	0.2
Lumetron Average	24.0	Author's Rating	8.3
Standard Deviation	8.0		0.2

Table 4c

Transmittance Values of Samples of Whole Strawberries rated 7.5 or less

Descriptive Group - Light (7 out of the 41 light samples--17%)

Sample Number	Percent Transmittance	Author's Rating
2	30.0	5.0
34	51.0	7.0
46	49.0	6.0
108	23.5	7.5
111	32.0	7.0
113	26.5	7.5
114	16.2	7.0
Average	32.6	6.7
Standard Deviation	12.9	0.9

Descriptive Group - Dark (8 out of the 30 dark samples--27%)

30	17.0	7.0
41	11.0	7.0
43	12.0	7.0
47	16.0	5.0
106	19.1	7.5
112	13.0	7.5
116	9.7	7.5
Average	14.0	6.9
Standard Deviation	3.4	0.9

Total Lumetron Average 23.3 Total Author's Rating 6.8
Standard Deviation 13.3 0.9

Table 5

Comparison of PMA Type Grades with Author's Rating

Sample Number	PMA Type Grade	Features Affecting Grade	Author's Rating
29	A	color just within grade	9.0
33	A		9.0
35	A	color just within grade	9.0
44	A		8.0
31	B	color and character	8.5
36	B	color and character	9.0
37	B	color, defects, character	9.0
39	B	uneven color	9.0
42	B	color and character	9.0
43	B	defects and character	7.0
47	B	defects and character	5.0
48	B	color and character	9.0
49	B	character	9.0
28	D	uneven color	8.0
30	D	uneven color	7.0
32	D	uneven color	8.0
34	D	color and character	7.0
38	D	uneven color	8.0
40	D	uneven color (B for defects)	8.5
41	D	uneven color	7.0
45	D	defects	9.0
46	D	character (B for color)	6.0

Table 6

Discrepancies between Grading Systems

SUBSTANDARD SAMPLES--PMA Type Grade "D"

Sample Number	Dockage Factor Under PMA	Author's Grading	Basis for Author's Evaluation
		Points	
45	defects	9.0	medium-light; no defects
40	color	8.5	light; 2 sepals; 2 mushy
28	uneven color	8.0	medium-light; some green
32	color uneven	8.0	cat-faces
38	color	8.0	dark
30	color differences	7.0	overripes and soft; culls
34	color, character	7.0	light, greenish; sort-outs
41	color	7.0	dark; grass blade
46	character	6.0	very light, all pink to green; sort-outs

PMA Type Grade "B" SAMPLES RECEIVING LOW RATING BY Author's System

43	defects, character	7.0	4 cat-faces, 5 softies, sloppy, dark color
47	defects, character	5.0	soft and broken; 2 stems; dark and 10% scorched; size under 5/8 inch.

The most discrepancy between the two systems is shown by sample 45 which received grade "D" (PMA type) on account of defects but was given a rating of 9 points in the author's evaluation and was noted as having "no defects". The defects, apparently, were judged not to be the kind which would appear as blemishes in preserve making. The two samples (43 and 47) which scored low in the author's evaluation but which graded well under PMA rules carried remarks of "soft", "sloppy", and "small size".

Subjective Color and Transmittance

Notes on the color of the whole berries which were made at the time of thawing out the sample have been used to divide the samples into 3 categories under the headings light, intermediate (or indeterminate), and dark. These findings are presented in Tables 7a, 7b, and 7c.

Although at the time of the examination such a listing was not planned, the descriptions based on these notes have rarely turned out at variance with the readings in the Lumetron. In a few instances wordings caused the sample to be rated as neutral when the transmission value given by the Lumetron placed it emphatically elsewhere. For instance, sample number 6, which fell into the intermediate group, had a very high transmission value. Other ones in this group which had unusually low readings were numbers 9, 10, and 114. Number 35 is the only sample which seems

Table 7a

RELATIONSHIP BETWEEN COLOR OF WHOLE BERRIES
AND AROMA OF THE PUREE

Section A: LIGHT COLOR GROUP

Sample Number	Notes on color	Percent Transmittance	Term describing the Aroma
2	light, tending unripe	30.0	
8	generally light	28.0	normal, fairly full
11	generally light	28.0	normal, feeble
18	fairly light, good	31.2	faint but normal
22	fairly light, uneven	27.0	normal, feeble
24	light, fair	49.0	
28	medium-light, greenish	32.9	feeble
32	medium-light, uneven	34.0	medium fresh
34	light, many greenish	51.0	faint, stemmy
35	medium-light, some darker	19.3	mild, fresh
39	light, 3 almost white	30.0	good, pleasant
40	light	44.0	mild, sweet
42	light, 3 green-tipped	27.0	light
45	medium-light, 1 light	31.0	fairly strong
46	all light	49.0	stemmy, haylike
48	light-medium; 2 darkish	35.0	greenish, pleasant
49	medium-light; 2 v. light	31.0	flat, faint
111	light; 4 v. light, 3 dark	32.0	faint, not pleasant
117	light, none scorched	--	faint, fresh, pleasant
Average		33.8	
Standard Deviation		8.7	

Table 7b

Section B: INTERMEDIATE COLOR GROUP

Sample Number	Notes on color	Percent Transmittance	Term describing the Aroma
1	mostly ripe, variable	28.0	
3	fine even red	27.0	
4	fine deep red	21.5	normal, med.-strong
5	fairly good, overripe	31.5	slight, immature
6	fairly good but variable	37.5	normal, not strong
7	uneven, a few scorched	27.3	slight
9	fairly good	16.0	
10	fairly good, a few dark	14.5	strong, slight sickly
14	not uniform, 3-4 scorched	24.0	normal, mild
15	uniform, 2 small scorched	18.2	normal
19	bright red, 2 scorched	17.5	normal, full and strong
20	bright red, 1 scorched	27.1	normal, fresh, faint
21	fair, slightly light	25.2	normal, med.-deep
25	fair, a few scorched	18.9	normal, med.-deep
26	fair, a few scorched	24.0	
36	medium-light, 2 scorched	18.0	normal, good
44	medium, even and good	24.0	bright, faint, light
101	medium, 4 half-scorched	23.0	fresh, med.-strong
102	good, 1 scorch, 2 greenish	23.0	fairly strong
105	medium, no overripes	25.0	strong, slight stemmy
107	medium, 3 scorch, 1 yellow	21.5	pleasant, slight stemmy
108	medium, 5 scorch, 6 yellow	23.7	faint, green, stemmy
109	dark; 3 pink, 1 green-end	23.6	pleasant, fairly strong
113	medium, 3 or 4 scorched	26.5	stemmy, sickly, dull
114	medium, 4 scorched	16.2	off-flavor
118	medium, very even	22.0	fresh, pleasant, good
119	medium, 3 yellow, 5 scorch	27.3	odd, sickly, fresh
Average		23.4	
Standard Deviation		5.1	

Table 7c

Section C: DARK COLOR GROUP

Sample Number	Notes on color	Percent Transmittance	Term describing the Aroma
13	dark, 4-5 scorched	15.0	
16	uniformly dark--too dark	22.2	sweet, not sickly
17	fairly dark, 2 lightish	19.5	normal, not sickly
29	dark, some scorched	20.5	slightly sickly
30	dark, some overripes	17.0	raw, fresh
31	dark, uniform	14.0	normal, sour-sickly
33	dark, some scorched	18.0	medium, mature
37	dark-medium	18.0	fresh, raw
38	dark, 2 slightly scorched	16.0	sweet, strong
41	dark, 2-3 scorched	11.0	sweet-sickly, dull
43	medium-dark to dark	12.0	dull, sweet
47	dark, 10% scorched	16.0	dull, sickly, off
103	dark, no variation	20.0	fresh, fairly light
104	dark, some less dark	19.0	pleasant, strong
106	medium-dark, 3 scorched	19.1	sickly-sweet, strong
110	medium-dark, 2 scorched	17.0	sickly-sweet
112	dark, one third scorched	13.0	dull, punk
115	medium to dark	15.1	sickly
116	dark to medium	9.7	sickly, slightly dull
120	medium-dark, 3 scorched	10.3	strong, slightly odd
121	dark, 4 scorched, 2 green	15.6	strongish, not sickly
122	dark except 2 yellows	17.2	sweet, only sl. sickly
Average		16.1	
Standard Deviation		3.4	

to have fallen completely out of place into the contradictory category by being in the light group through its wording and in the dark group through its Lumetron reading.

The 19 samples of whole berries which were described as light in color gave transmittance readings which fell into the range of 19.0% to 51.0%, with an average of 33.8% and standard deviation of 8.7%. There were 22 samples with a description suggesting darkness in the color, and their range ran from 9.7% to 22.2% in transmittance, with an average of 16.1% and standard deviation of 3.4%. According to the wording, 27 samples had the intermediate shade but it was one which often, due to laxity in description, was really an indeterminate one. Their range ran from 14.5% to 37.5% and averaged 23.4% with standard deviation of 5.1%.

Subjective Color and Aroma

It should be pointed out that differences in aroma are clearly distinguishable and therefore they can be classified. The words used to describe aroma in this report, when listed alongside the subjective color ratings, were found to fall into similar groups. Such descriptive terms as "faint", "fresh", and "stemmy" fell with the light color category. Such terms as "normal", "medium", and "pleasant" fell with the intermediate color group. Such terms as "strong", "dull", "sweet", and "sickly" fell in the dark colored group.

In Table 7a, 14 of the 17 samples which fell into the "light" category (82%) had descriptions of aroma which suggested "faint" or "fresh", 2 were "normal" or "pleasant", and 1 was "fairly strong". In the intermediate color group 13 samples (59%) had aromas which followed the "normal-pleasant" pattern, 5 were "faint or immature", and 4 were "strong" or "sickly". Of the 22 aromas which fell into the dark color group, 16 (73%) had wording indicating "strong" or "sickly-sweet", while 3 were "fresh-raw", and 3 were "normal-pleasant". From this table it can be seen that the wording of the aroma sometimes placed a sample into more than one category. For example, samples 113 and 119 each combine two extremes of the aroma pattern since they are described as having a "fresh and stemmy" aroma as well as being "sickly and odd". In such instances the notes describing color offer the clue that the samples contained both immature and overmature berries. This information had been concealed in the Lumetron readings through the blending of the color differences.

When all the verbal descriptions of aroma were brought together under their 3 headings in Table 8, 21 of the "fresh-raw" aroma category showed an average percent transmittance in the Lumetron of 30.0, ± 9.2, 18 of the "normal-pleasant" aroma category showed 23.2%, ± 5.1, and 21 of the "strong-sickly" aroma category showed 17.1% ,

Table 8

THE AROMAS GROUPED WITH THE COLOR CATEGORIES

"FRESH-RAW" group Transmittance percent		"NORMAL-PLEASANT" group Transmittance percent		"STRONG-SICKLY" group Transmittance percent	
28.0		28.0	LIGHT	31.0	LIGHT
31.2		30.0	COLOR		
27.0					
32.9					
34.0				14.5	
51.0		21.5		23.0	MEDIUM
19.3	LIGHT COLOR	37.5		26.5	
44.0		24.0		16.2	
27.0		18.2			
49.0		17.5			
31.0		27.1			
35.0		25.2	MEDIUM	22.2	
32.0		18.9	COLOR	20.5	
		18.0		14.0	
		23.0		16.0	
		25.0		11.0	
31.5		21.5		12.0	
27.3		22.0		16.0	
24.0	MEDIUM COLOR			19.0	DARK
23.7				19.1	
27.3				17.0	
		19.5		13.0	
		18.0	DARK COLOR	15.1	
		23.6		9.7	
17.0				10.3	
18.0	DARK COLOR			15.6	
20.0				17.2	
Average 30.0		23.2		17.1	
Standard Deviation 9.2		5.1		5.3	

± 5.3. These figures compare with $33.8\%, \pm 8.7$, $23.4\% \pm 5.1$ and $16.2\%, \pm 3.4$, the corresponding averages of the subjective ratings of color along.

Viscosity

An estimate of viscosity, which provided a comparison between the flow strengths of the puree lots, was made for 43 samples. 51% were classified as thick, 21% were thin, and 28% were rated "in between". The average Brix reading of the viscosities marked thick was $10.28^{\circ}, \pm 1.1$, that of those called medium viscosity was $9.76^{\circ}, \pm 1.4$, and that of the thin viscosity was $9.56^{\circ}, \pm 1.1$. These data are to be found in Table 9.

Soluble Solids and Percent Transmittance

When plotted on graph paper these data show no clustering into a curve which would indicate that the higher Brix readings carry lower transmittance.

Excess Water and Softness

In only four plants was the water-drip which accompanied the fruit over the end of the belt noted as considerable. The average reading for soluble solids in the 16 samples representing these plants was 9.7° Brix, compared to the over-all average of 9.77° Brix.

Expressions such as "soft" or "juicy" sometimes appeared in the descriptions of the freshly thawed berries.

Table 9

The Soluble Solids of Strawberries Grouped as to the Viscosities of their Purees

THICK		MEDIUM		THIN	
Sample Number	Percent Soluble Solids	Sample Number	Degrees Brix	Sample Number	Degrees Brix
49	8.00	119	7.75	39	8.25
107	8.50	108	8.00	11	8.50
46	9.10	116	8.10	30	8.80
102	9.25	101	9.00	117	8.85
111	9.25	40	9.25	26	9.50
42	9.50	45	10.00	122	9.75
109	9.60	112	10.00	32	10.00
118	9.75	41	10.10	38	10.60
10	10.00	106	10.10	113	11.75
110	10.00	36	10.50		
24	10.25	115	12.10		
105	10.25	114	12.20		
48	10.50				
120	10.50				
47	11.00				
43	11.25				
44	11.25				
103	11.25				
34	11.50				
121	11.60				
104	11.70				
33	12.25				
Average	10.28		9.76		9.56
Standard Deviation	1.12		1.45		1.12

Twenty samples rated in this category are listed in Table 10. These 20 samples had an average soluble solids content of $10.18^{\circ}, \pm 1.41$ compared to the average for all samples of $9.77^{\circ}, \pm 1.27$. Furthermore this group formed purees which graded "thick" in viscosity in 12 out of 19 samples, or 63%.

Table 10

Soluble Solids and Subjective Viscosity Ratings of Samples Noted as Juicy or Soft

Sample Number	Conditions noted	Degrees Brix	Subjective Viscosity Rating
33	water and juice	12.25	fairly heavy
37	watery	8.50	
40	2 berries mushy	9.25	medium
43	sloppy	11.25	thick
47	soft	11.00	thick
101	juicy	9.00	medium
102	juicy	9.25	medium thick
103	juicy	11.25	thick
104	juicy	11.70	very thick
107	juicy	8.50	medium thick
108	juicy	8.00	medium
109	juicy	9.60	thick
112	juicy	10.00	medium
114	very soft, also seedy	12.20	medium
115	fairly juicy, 3 seedy	12.10	medium thick
116	soft, fairly juicy	8.10	medium
118	flabby, juicy	9.75	thick
120	several flabby, juicy	10.50	thick
121	a quarter flabby	11.60	very thick
122	third were sloppy, juicy	9.75	thinnish
Average		10.18	
Standard Deviation		1.41	

DISCUSSION

The purpose of this research has been to explore quick, objective ways of determining the quality of strawberries for manufacture in order to replace or to supplement decisions based upon subjective evaluation. At present the only official way of grading is by the Grade standards of the Production and Marketing Administration. Apparently the PMA criteria are based upon the viewpoint of the consumer (usually the housewife) at retail level. Furthermore the official judgment is founded upon those physical considerations which are readily visible. It also omits the two broad categories of internal soluble contents and of contamination by material which is virtually invisible to the naked eye. These are important in manufacture.

The data from these studies illustrate that grading and making decisions based upon personal opinion are subject to human error and bias. A definite disagreement showed up in 3 out of the 22 cases where the classification given by a committee working under grade rules followed that given by a separate arbitrary grader. One of these samples received a rating of grade "B" under the PMA rules when it was made up entirely of culls. The berries in the sample had been selected out as waste either by the machinery or by the crew of inspection women. Under the author's system of grading of berries for manufacture this sample was classified as unacceptable due to small size, dark color, and soft condition.

The counts on sediment and mold, and to a smaller extent those on insects, which are factors which reflect the working conditions within the plants, can be relied upon to be fairly typical of such readings, and they should be applicable to subsequent tests made in future years. The readings which were more strongly affected by weather, as for example the values obtained for soluble solids and for color, are less likely to conform to those of other seasons. The weather for the period represented here was of the dry and very sunny type.

Several requirements must accompany any new tests to make them acceptable. Speed is one of the most important features that a test should have since it will be necessary to handle large groups of samples during periods of heavy production. It was the author's aim to secure numerical ratings of characteristics of an individual sample in a short time, preferably in less than 10 minutes. To secure the readings for the subsequent members of a group of samples might take only a fraction of that time.

Cost is another requisite. A piece of equipment, if recommended, should be available at a price which will not appear excessive to a small processor. Of the instruments used in this paper the most expensive was, perhaps, the

Lumetron colorimeter. At a cost of $150.00 it would probably be used extensively without much complaint considering its possible further adaptability for arbitrating the degree of ripeness with the grower. Still another need is that the process be simple enough that a supervisor can readily train an operator.

The author was not successful in putting all the results on a numerical basis. He was not able to eliminate all the subjective decisions; in fact the item of aroma was brought forth as a new consideration. The results which have been obtained show that it will be possible some day to fix for most of the important qualities a range of figures which will be precise enough to represent a description. That decision is as far as we are able to go with confidence at present.

In order that figures obtained from the methods introduced by this paper are to be able to stand comparison with each other when obtained in the laboratories of different processing plants, the procedures upon which they are based must be standardized. All the equipment must turn out results which are uniform. The analytical processes must be carried out under standard conditions as to time and mechanical speed.

For checking contamination with dirt and minute insects positive answers have been obtained both through the devising of laboratory methods and through indicating the selectivity which these methods reveal towards rating the washing techniques of the factories. The laboratory procedure for isolating dirt particles prior to counting them dovetails with that needed for separating the insects from the sample.

The separatory funnel used for these determinations should have a capacity of at least 1 litre, and it should have a shape which is stubbier and more bellied out than the standard chemical model in order to allow the easiest movement up and down for floating particles. Its top should be of the close-fitting, insert type and should have a solid, level base which can exclude air as it is fitted down onto liquid. The outlet tube and its stopcock should be of generous capacity. Unless a method of separating the seeds has been used, as has been done here by pureeing, the heavy portion from the funnel will have to be screened again in some way in order to separate dirt from seed.

The dirt is virtually invisible except under the microscope. A system of counting particles is suggested for grading purposes. However factors such as what evaluation ought to be put on particles of sand which stay whole; as against particles of soil which form fragments, will have to undergo more study.

The insects which were obtained in these tests were small. In the processing of strawberries, larger insects are rarely left on, and they could not go through the screen of a puree machine in any case. Fragments of the larger types were rarely seen, but two or three small worms, one or two millimeters long, were found, and they would have escaped attention under routine inspection. Although this procedure, which stresses free visibility under the microscope has merit, other considerations indicate that there should be a change in the process to let all insects stay in the pulp to be extracted by oil. The detection of particles of soil also indicate that a similar change is needed. Comparative trials might in future be made with an instrument similar to a Waring blender as well as with the puree machine.

When counting the insects a sure method for avoiding bubbles in the oil was not found. Many lots of oil were so clear of distracting particles such as bubbles that the insects could be counted in them accurately in less than two minutes, but other samples were so bubbly that insect detection was tiresome. Bubbles could lead to error in counting dead mites which they resemble. The grid itself may have been responsible for including some bubbles. It was never determined whether it was best to lay the grid in the dish of oil before or after the layer of oil was raised to its height within the grid framework. Nor was it determined whether tapping the grid was effective in dislodging attached bubbles and particles.

Generally a note was made to record those in the bubbly state in the expectation that this condition would prove to be linked with overripeness or excessive mold. Evidence does lean in favor of moldiness and overripeness adding to this condition. One of the worst cases appeared in a puree which had been stored for 48 hours at 36° F. Another sample (No. 8) which had the highest mold count also had more than 50 living mites. The simple precaution of boiling the sample before starting the oil extraction was omitted, and similarly no check was taken to see whether a change in the temperature of the liquid in the observation dish was contributing to formation of bubbles.

The problem of mold determination is very much like that already solved for tomato puree. No other suggestions are offered. An acceptable maximum number of positive mold fields might some day be allowed by the federal control authorities.

The Lumetron colorimeter will measure changes in color intensity reliably, and is especially sensitive to the degree of redness. The color had to be extracted first from the pulp. Doing this by alcohol seemed more simple than by using a centrifuge. Alcohol gave clearer solutions and ones which showed an increased range of color intensity. This process also saves the cost of the centrifuge needed for the water method.

No other way of determining color was tried. In parallel research and in using other equipment Shah (57) was able to utilize the puree without extraction, and probably he could save time that way. The use of the spectrophotometer was considered but the lack of simplicity of operation and expense were against its adoption.

Groupings of color fall quite readily into the three classifications chosen. Noticeable differences show up between samples in color, in aroma, and to a small extent in average soluble solids. The type which was called "intermediate" is probably the closest to the ideal condition which all utilizers of strawberries for manufacture desire. It has a characteristic flavor and one which is always pleasant unless its color rating happened to be a balanced blend of the light and dark extremes. The average of its transmittance readings was 23.4%, $\pm$ 5.1 at 490 millimicrons.

Manufacturers who want fruit on the lighter colored side would probably specify a type which came as close as possible to this reading. Others who like a dark-appearing type would specify in the same way but from the opposite side of the scale. The averages of the light and dark colored groups, then, 33.8% , $\pm$ 8.7 and 16.1%, $\pm$ 3.4, would not at all be representative for these particular purposes. This state of affairs indicates the need to undertake a consumer-acceptance study and to tie it statistically to a numerical rating.

The important feature of relating the degrees Brix (or soluble solids, or sugar content) to data on free acidity and depth of color, has not been studied in this work. When the readings of degrees Brix were plotted on graph paper against either of these factors the points were too scattered to represent a trend. The amount of soluble solids is apparently influenced by conditions which conflict with one another.

No mention of aroma was found in the literature. Sometimes airtight containers of frozen strawberries, when opened for inspection, were noticed to carry a strong, unpleasant odor even while frozen solid. This odor is probably linked to the author's "unpleasant-sickly" grouping. Then the degrees Brix and the aroma might be useful considerations in future studies which link these analyses with consumer preference.

SUMMARY AND CONCLUSIONS

1. Except in analytical and detailed processes there was little published literature on methods of measuring quality in fruit and fruit products. Most of the physical methods of examination are recent and had not been reported upon at the time of the research.

2. All the strawberry packing plants in the Willamette Valley area of Oregon and a few in Washington were visited. Those from which samples were drawn were critically surveyed as to operation and sanitary conditions.

3. Failings in the interpretations made under the PMA grading system for strawberries are indicated. Due to their subjective basis, these evaluations and the author's own subjective evaluations disagree with each other strongly at times. Both show disagreement with the impersonal ratings applied here.

4. A device for viewing insects under the microscope has been introduced. It allows minute creatures to be inspected in their free un-cramped shape while in liquid. This makes them more visible and recognizable than when searched for on filter paper.

5. Color data which were obtained by subjective and objective methods, and aroma which was obtained by subjective methods, were grouped into three categories for better comparison. The light colored group had an average

of 33.8%, ± 8.7 transmittance, the intermediate group had one of 23.4%, ± 5.1, and the dark colored group had 16.1%, ± 3.4. Color, whether measured subjectively or by photometer was rather closely related to aroma.

6. The nineteen factories were rated on the equipment used and on the quality of work done. Based upon the criteria used three categories were formed and for these the average counts of mold, sediment and insects were obtained. In the order "above-normal", "normal", "below-normal", the mold count averaged 4.4, ± 4.2, 7.0, ± 9.2, 7.5, ± 7.8; the sediment count ran 16.3, ± 19.0, 32.1, ±30.0, 44.5, ± 41.2; and the insect count 4.6, ± 3.5, 6.9, ± 13.3, 23.4, ± 65.4.

7. The defects of watery condition and softness-after-thawing were not revealed in the readings of degrees Brix.

BIBLIOGRAPHY

1. Association of official agricultural chemists. Official method of analysis. 7th ed. Washington, D.C., 1950. 901p.

2. Bollinger, H. M. Titration of acids in fruit products. Journal of the Association of official agricultural chemists 28:507-518. 1945.

3. ________________ Titration of acids in fruit products. Journal of the Association of official agricultural chemists 30:266-274. 1947.

4. Beattie, H. G., K. A. Wheeler and Carl S. Peterson. Changes occurring in fruit juices during storage. Food research 8:395-404. 1943.

5. Beryukov, D. P. Determination of dry substance in onion by refractometer. Konservnaya i plodoovoshchnaya promyshlennost 10:33. 1939. (Chemical abstracts 35:5205. 1941)

6. Berkhart, Leland. Firmness of strawberries as measured by penetrometer. Plant physiology 18:693-698. 1943.

7. ________________ and R. A. Lineberry. Determination of vitamin C and its sampling variation in strawberries. Food research 7:332-337. 1942.

8. Culpepper, Charles W., S. Caldwell and H. H. Moon. A physiological study of development and ripening in the strawberry. Journal of agricultural research 50:645-696. 1935.

9. Darling, C. A. Methods of determining numbers of micro-organisms in tomato products. Geneva, Cornell university, 1922. 56p. (New York. Agricultural experiment station. Technical bulletin 91)

10. Davis, Dale S. Determination of moisture in honey. A monograph. Chemical analyst 29:87. 1940.

11. Demortier, G., A. Parmentier and R. Lemaitre. Conservation tests on Belgian fruit juices. Bulletin del 'institut agronomique et des stations de recherches de Gembloux 7:297-359. 1938. (Chemical abstracts 33:3475. 1939)

12. Eckart, Hanns. Refractometry as an aid in research on fruit juices. Zeitschrift fur Untersuchung der Nahrungs und Genussmittel sowie der Gebrauchsgegenstande 50:196-204. 1925. (Chemical abstracts 20:632. 1924)

13. Gortner, Willis A., Faith Fenton, Frances E. Volz and Ella Gleim. Effect of fluctuating storage temperatures on quality of frozen foods. Industrial and engineering chemistry 40:1423-1426. 1948.

14. Grawemeyer, Elizabeth A. and Marion C. Pfund. Linespread as an objective test of consistency. Food research 8:105. 1943.

15. Guillaume, A. and M. Michon. Analytical study of fruit and vegetable juices. Annales des falsification et des fraudes 32:301-319. 1939. (Chemical abstracts 34:1763. 1940)

16. Hadorn, H. Estimation of solids and water in fruit juices and concentrates. Mitteilungen aus dem Gebiete der Lebensmitteluntersuchung and Hygiene 36:324-334. 1945. (Chemical abstracts 40:3539. 1946)

17. Halvorson, H. A. Investigation of the methods of determining water in agricultural products. Journal of the Association of official agricultural chemists 20:435. 1937.

18. Hansen, Elmer and George F. Waldo. Ascorbic acid content of small fruits in relation to genetic and environmental factors. Food research 9:453-461. 1944.

19. Harris, Kenton L. Some applications of insect separation methods to entomology. Proceedings of Entomological society of Washington 45:19. 1943.

20. Harrison, William H. The insect fragment count. Food industries 9:306. 1937.

21. Hartmann, Bernhard George. Analysis of Catawba grape juice. Journal of the Association of official agricultural chemists 8:716-725. 1925.

22. ______________________ Determination of acids, color, and tannin in fruit products. Journal of the Association of official agricultural chemists. 26:444-462. 1943.

23. Heinze, Peter Herman and E. A. Murneek. Comparative accuracy and efficiency in determination of carbohydrates in plant material. Columbia, University of Missouri, 1940. 23p. (Missouri. Agricultural experiment station. Research bulletin 314)

24. Hinton, C. L. and T. Macara. Composition of some jam fruits. Analyst 65:540-559. 1940.

25. Hodges, F. Allen. Determination of extraneous materials in fruit products and beverage materials. Journal of the Association of official agricultural chemists 31:329-331. 1948.

26. Hoppler, F. Viscosity of fruit juices and syrups. Zeitschrift fur Untersuchung der Lebensmittel 85:45-53. 1943. (Chemical abstracts 38:420. 1944)

27. Horner, G. Determination of total solids in canned tomato products. Journal of the Society of chemical industry. 59:74-78. 1940.

28. Howard, Burton James. Use of microscope in food adulteration. In Yearbook of the U.S. Department of agriculture, 1907. Washington, Govt. printing office, 1908. pp.379-384.

29. ______________________ Fragment count method for tomato products. Canning age 18:324. 1937.

30. ______________________ and C. H. Stephenson. Microstudies on tomato. Washington, Govt. printing office, 1917. 24p. (U.S. Department of agriculture. Department bulletin 581)

31. Jessep, H. G. Rapid determination of soluble solids. Proceedings of the society of chemical industries, Victoria. 39:180. 1939. (Chemical abstracts 33:9182. 1939)

32. Kamer, J. H. and N. F. Jansen. Determination of specific gravity of extracts of syrup, jam, etc; based on Jacobsen-Lindestrom Lang. Chemisch Weekblad 42:103-106. 1946. (Chemical abstracts 40:4155. 1946)

33. Kimbrough, William Duke. Quality of strawberries as influenced by rainfall, soil moisture, and fertilizer treatments. Proceedings of the American society of horticultural science 27:184-186. 1931.

34. King, J. Adulteration of conserves, with special reference to pectin and agar. Analyst 50:371-383. 1925.

35. Koltyarenko, M. and A. Popel. Determination of insoluble substances in fruits and berries. Spirto-vodochnaya promyshlennost 10:23-25. 1938. (Chemical abstracts 34:825. 1940)

36. Kramer, Amihud, R. B. Guyer and H. R. Smith. A rapid objective method for measuring the color of raw and canned tomatoes. Proceedings of the American society of horticultural science 51:381. 1948.

37. Kudryavtseva, M. A. The chemical composition of strawberries. Biokhimiya kulturnykh rastenii 7:317-318. 1940. (Chemical abstracts 35:2928. 1941)

38. Macara, T. Composition of fruits for jam. Analyst 31:35-43. 1931.

39. Mayfield, Helen L. and Jessie E. Richardson. Ascorbic acid content of strawberries and their products. Bozeman, Montana State College, 1943. 16p. (Montana. Agricultural experiment station. Bulletin 412)

40. Munson, L. S., L. M. Tolman and Burton J. Howard. Fruits and fruit products: chemical and microscopical examination. Washington, Govt. printing office, 1902. 107p. (U.S. Department of agriculture. Bureau of chemistry. Bulletin 66)

41. Needham, George H. and Carl R. Fellers. Application of the Howard method to the detection of spoilage in berry products. Journal of the Association of official agricultural chemists 8:312-327. 1925

42. Official referee. Report on fruit products and tomato. Journal of the Association of official agricultural chemists 31:51. 1948

43. Osborn, Robert Ambrose. Determination of water-insoluble solids of fruit and fruit products. Journal of the Association of official agricultural chemists 30;260-265. 1947.

44. Pearce, J. A. and Suzanne Jegard. Measuring the solids content of honey and of strawberry jam with a hand refractometer. Canadian journal of research F27:99-103. 1949.

45. Pederson, Carl S. and Harold G. Beattie. Buffering effect of fruit juices. Food research 8:405-408 1943.

46. Pien, Jean and H. Meinrath. Detection of adulteration of fruit juices. Annales des falsifications et des fraudes 31:282-290. 1938. (Chemical abstracts 32:7593. 1938)

47. Prange, G. Microdetermination of alcohol in fruit products. Vorratspflege und Lebensmittelforshung 4:553-572. 1941. (Chemical abstracts 37:5796. 1943)

48. Pritzker, J. Standards of alcohol-free fruit juices. Mitteilungen aus dem Bebiete der Lebensmitteluntersuchung und Hygiene 35:226-229 1944. (Chemical abstracts 39:4991. 1945)

49. ____________ Fruit juice concentrates. Mitteilungen aus dem begiete der Levensmitteluntersuchung und Hygiene 25:230-238. 1944. (Chemical abstracts 39:4991. 1945)

50. Production and marketing administration standards for grades of frozen strawberries. U.S. Department of agriculture. Washington, D. C. 1949.

51. Robinson, Willard Bancroft, et al. Chemical composition and freezing adaptability of strawberries. Geneva, Cornell university, 1947. 14p. (New York. Agricultural experiment station. Bulletin 726)

52. Saburov, N. V. and M. I. Kalebin. A comparative investigation of different methods for the determination of fruit acids. Khimicheskii Referativnyi Zhurnal 2:82. 1939. (Chemical abstracts 34:1407. 1940)

53. Sale, John Walter. Interpretation of chemical analyses of preserves and jams. Fruit products journal 17:331-336. 1938.

54. Schrader, Lee A. and H. D. Scott. Quality comparisons of strawberry varieties as affected by processing with the freezing method. Proceedings of the American society of horticultural science 50:246-250. 1947.

55. Schuphan, W. Alteration of the vitamin C content and caloric value of German varieties of strawberries by weather conditions. Biochemische Zeitschrift 311:151-162. 1942.

56. Scott, Leland Edwards and Lee A. Schrader. Ascorbic acid content of strawberry varieties before and after processing by freezing. Proceedings of the American society of horticultural science 50:251-253. 1947.

57. Shah, Jayantilal H. Color estimation of frozen strawberries by reflection-meter, spectrophotometer and visual grading. Master's thesis. Corvallis, Oregon State College. 1951. 49p.

58. Shimer, Stanley Reisz and H. J. Purinton. The ascorbic acid and carotene content of fresh and frozen New Hampshire berries. Durham. New Hampshire. 1948. (New Hampshire. Agricultural experiment station technical bulletin 92. 1948)

59. Somogyi, M. A reagent for the copper-iodometric determination of very small amounts of sugar. Journal of biological chemistry 117:771-776. 1937.

60. Sondheimer, Ernest and Z. I. Kertesz. Anthocyanin pigments: a colorimetric determination in strawberries and strawberry products. Analytical chemistry 20:245-248. 1948.

61. ________________ The anthocyanin of strawberries. Journal of the American chemical society 70:3476-3479. 1948.

62. Talon, Raymond. Determination of the water content of jellies, fruit pastes, preserves. Bulletin de l 'association des chimistes 62:149-158. 1945. (Chemical abstracts 40:3540. 1946)

63. Tissier, Francois. Detection of added water to wines. Annales des falsifications et des fraudes 7:251-254. 1914.

64. Villiers, A. P., M. B. Collin and G. L. Fagolle. Some tests for adulteration in fruit products. Journal de pharmacie et de chimie 3:467-475. 1926.

65. Wilder, C. D. and M. A. Joslyn. Estimation of worm and insect fragments. Journal of the Association of official agricultural chemists 20:648. 1937.

66. Wildman, J. D. A simple method for separating certain insects from food products. Science 75:268. 1932.

67. Willberg, B. Detection of added water in the juice of berries. Finska Kemistsamfundet Festskrift-Juhlajulkaisu 312-324. 1944. (Chemical abstracts 41:5648. 1947)

68. Winton, Andrew Lincoln and Kate B. Winton. The microscopy of vegetable foods. New York, Wiley, 1916. 701p.

69. Yang, Ho-Ya. Spectrophotometric and chromatographic studies of the principal pigments in Evergreen blackberries and Alicante Boughet grapes. Ph.D. thesis. Corvallis, Oregon State College. 1940. 37p.

70. Yao, Ka-Teng. Variation in the sugar and acid content of frozen Marshall strawberries grown in different areas of the Pacific Northwest. Master's thesis. Corvallis, Oregon State College, 1951. 36p.

APPENDIX

Appendix Table 1

Changes in the pH and in the Percent Transmittance of Light in Purees Held Overnight at 34° F

Freshly Tested

Sample Number	pH	Percent Transmittance
34	3.48	51.0
35	3.36	19.3
36	3.46	18.0
37	3.40	18.0

Held Overnight

Sample Number	pH	Percent Transmittance
34	3.18	58.0
35	3.04	20.5
36	3.26	20.0
37	3.25	18.2

Appendix Table 2

Percent Transmittance Readings of the Same Sample Under Filters of Different Wave Lengths

Sample Number	pH	Filter Rating: 490 mμ Percent Transmittance	Filter Rating: 530 mμ Percent Transmittance
4	4.56	23.2	23.1
42	2.38	6.5	6.1
45	3.11	6.8	6.6
46	3.76	32.0	33.3
46	3.81	35.5	35.6
47	3.96	7.5	7.2
48	4.43	32.8	32.5
49	4.14	12.8	12.4