AN ABSTRACT OF THE THESIS OF

Visith Chavasit for the degree of Master of Science in Food Science and Technology presented on December 20, 1984.

Title: A Study of Factors Affecting the Efficiency of Maturity Separation of Peas by Sodium Chloride Brine Flotation

Abstract approved: ______________________________
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The problem in green pea grading system by using brine flotation is loss of some less mature peas (generally regarded as higher in quality and price) in the sinker fraction (lower quality). Green peas were sampled from the production line as follows: (1) blanched but ungraded peas, (2) floater fraction, and (3) sinker fraction. Peas from the floater and sinker fractions were tested using the standard brine flotation test (United States Standards for Grades of Frozen Peas, 1959). Using sodium chloride salt brine as the separation medium, the blanched but ungraded peas were used to test the effect on percent floaters caused by: (1) change in brine concentration, (2) change in brine temperature, (3) change in pea temperature. Again, the blanched but ungraded peas were used to test the effect of underskin air on

percent floaters, using sucrose syrup as the separation medium. The relationships between change in percent floater peas and maturity of the floater and sinker fractions were determined by using Alcohol Insoluble Solids (AIS) analysis as the maturity reference method. The nature of problem was identified, when a high percent (44.9%) U.S. Fancy grade floaters was found in the sinker fraction from the factory. The study showed that the percentage of floaters was significantly ($p=0.05$) influenced by brine concentration, brine temperature, pea temperature, and retention of air under the skin of the peas. Regression analysis of the data for the first three factors indicated that rate of change in percent floaters was greatest with brine concentration, and least with pea temperature. The change in maturity of floater and sinker fractions as determined by AIS analysis showed a close positive relationship between the change in percent floaters produced by change in the treatment conditions. Again, AIS results showed that residual underskin air in the intact blanched peas significantly affected the accurate separation by a false increase in buoyancy of borderline maturity peas (AIS was in between floater's and sinker's) in the flotation process. The underskin air factor was the least important factor affecting percent floaters when compared with the other factors of brine concentration, brine temperature, and pea temperature.

A Study of Factors Affecting the Efficiency of Maturity Separation of Peas by Sodium Chloride Brine Flotation

by

Visith Chavasit

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed December 20, 1984

Commencement June 1985

APPROVED:

Associate Professor of Food Science & Technology in charge of major

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Dean of Graduate School

Date thesis is presented December 20, 1984

Typed by author for Visith Chavasit

ACKNOWLEDGEMENTS

I want to express my appreciation to my major professor, Mr. George W. Varseveld, for his guidance during the development of this thesis with so much concern. To Dr. David R. Thomas for his statistical advising and Mrs. Pachitjanut Siripanich for her final statistical checking. To Dr. Harland I. Padfield, Dr. Donald L. Mac Donald, and Dr. Allen F. Anglemier for accepting to serve on my commitees. To Dr. Carlos Kienzle-Sterzer for some of his comments.

I wish to express my thanks to Stayton Company at Brooks for providing the pea samples and Smith Frozen INC. at Weston for some valuable information.

Acknowledgement is also made to all fellow graduate students for their helpfulness and friendliness, and especially to Jose Flores for his help concerning the word-processor.

I still remember the late Dr. Arthur F. Badenhop who initiated this project and Dr. Morris M. Montgomery for his concern.

Very special appreciation goes to my parents for their love and unfailing support.

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INTRODUCTION

As green peas (Pisum sativum) become more mature, changes in physical, chemical and morphological properties occur. These changes affect the acceptability of pea products to the consumers. The low maturity peas are regarded as higher in quality and value for canned and frozen products. By considering the changes in physical, chemical and morphological properties, various methods and several instruments have been developed for the measurement or analysis of maturity in green peas. The maturity data are needed in order to establish the price paid to the grower, to segregate peas into processing grades and to determine utilization. The maturity methods most widely applied in commercial processing systems are screen sizing and brine separation, and various types of equipment have been developed or improved by using these basic ideas. Under some growing conditions, size of peas does not increase with maturity of peas. Therefore a combination of size and density grading has been practised by processors, particularly canners, to accomplish maturity separation of peas. However, pea processors continue to experience problems of incomplete or inaccurate separation of peas of varying maturity within the raw product lot using present procedures and equipment. In the resulting separation, some low maturity, higher quality peas which generally would be separated as floaters in a density separation, would segregate to the more mature sinker fraction (Mc Gowan, 1983). Many factors such as turbulance of the brine solution, overload of peas in the grader, temperature differential between the peas and brine, and underskin air can be the causes of the inaccuracy. The temperature differential between the peas and brine is mentioned as a major factor (Key Equipment Company, 1966).

The objectives of this thesis are:

1) to determine the significance of brine and pea temperature differential as causes of incomplete separation of peas of different maturity by brine flotation,
2) to identify some methods of improving the accuracy of the pea brine flotation grading system to separate peas of different maturity.

LITERATURE REVIEW

Brine flotation test for quality control

The brine flotation test utilizes salt solutions of various specific gravities to separate green peas according to maturity (United States Department of Agriculture, 1959). It is the only procedure which fractionates the samples on a maturity basis, whereas all other methods whether chemical, physical, or mechanical give a value which indicates the average maturity of the sample (Lee, Whitcombe and Hening, 1954). The brine flotation test, however does not reflect toughening of skins (Makower, 1950). Some earlier researchers regarded the brine flotation test as a fair basis for buying peas (Muench, 1933). However, while simple and fairly rapid to execute in the laboratory, the method was not considered practical under grading station conditions. Mechanical instruments were introduced to measure fresh pea tenderness and these superseded the flotation techniques although the latter were used by many workers to evaluate the instruments during their development (Makower, 1950; Voisey and Nonnecke, 1973). Because the brine flotation methods for measuring maturity in frozen peas are based on the density, These and the direct measure of pea density suffer from the same basic weaknesses. According to Makower et al. (1953), these weaknesses include the narrow range of densities involved, the vulnerability of the measurement to small changes in temperature and concentration of liquid, the effect of residual entrapped air, the influence of time as the peas absorb solutes and release water, thereby changing the density of both the peas and solution.

Separation media

Bitting (1909) stated that the proper specific gravities of sodium chloride salt brine for separating peas into three maturity grades were 1.040 and 1.070. Later, the United States Department of Agriculture published Standards for Grades of Frozen Peas (sixth edition 1959) containing maximum sinker tolerances for each grade of frozen peas as determined by a standard brine flotation test. The listed tolerances were: 10 percent by count of peas (skins removed) that sink in 10 seconds in 13% salt solution for grade A, 12 percent by count of peas (skin removed) that sink in 10 seconds in 15% salt solution for grade B, and 16 percent by count of peas (skins removed) that sink in 10 seconds in 16% salt solution for grade C. In case of canned pea standards, the concentrations of salt solutions used for quality control were somewhat lower than the standard for the frozen peas (United States Department of Agriculture, 1955). In order to solve the solute absorption problem, sugar syrups were suggested to replace sodium chloride salt brines because sugar syrup has a much slower diffusion rate. The number of floaters in sugar syrups can be held constant for 3 minutes whereas it will decrease in sodium chloride salt brine in just 10 seconds (Makower, 1957). The sugar syrup at a given specific gravity gives the same percent floaters as the salt brine at the same specific gravity (Witebsky and Burr, 1951). Higher costs and sanitation problems were disadvantages in the use of sugar syrups rather than salt brine as the flotation medium (Makower, 1957). Today, sodium chloride salt brines are still used as the separation media in both quality grader and in the quality control procedure for testing graded products (Mc Gowan, 1983).

Temperature effect on density

When the temperature of a liquid, such as water,rises the mean distance between the molecules of the liquid increases, and thermal expansion occurs. This expansion, with increasing temperature, will produce a decrease in density (Tabor, 1969). In a solid, the average distance between atoms increases when the temperature is increased. This leads to an expansion of the whole solid body and thus there is a small decrease in density (Kingsbury, 1965;

Resnick and Halliday, 1968; Tabor, 1969). Because heat tends to reduce the density of a solid such as a green pea, warm peas have a tendency to have lower density than their normal density level. The opposite is true where cold peas are put in warm brine, and the peas tends to have higher density than their normal density level (Key Equipment Company, 1966). In 1946, Smith and Kramer suggested that the proper temperature of both the brine solution and the peas in the brine flotation test was close to 68°F. Lee, Whitcombe and Hening (1954) suggested that the brine flotation test should be done at room temperature, and that the peas and the brine be at the same temperature. The United States Department of Agriculture (1959) specified in the sixth edition of US Standards for Grades of Frozen Peas that the brine solution and the pea sample in the brine flotation test should both closely approximate 20°C (68°F). For the most accurate separation, the temperature of the brine in the quality grader should not exceed 80°F (Key Equipment Company, 1966).

Underskin air affecting density, grading system, and quality control system

When green peas are harvested, they take oxygen from the air and give off carbon dioxide (Kohman, 1933). Lee (1941b) mentioned that the specific gravity test for raw vegetable was found to be unreliable, probably because of the presence of air in the tissue; blanching of the sample before the test gave a higher correlation result with the sensory test than did the non-blanched sample. Makower (1950) concluded that underskin air severely limited the measurement of tenderness and maturity in peas by density and specific gravity methods. The removal of air from around the raw peas is necessary, in order to give a true separation of floaters and sinkers of any given lot in a brine solution. Many processing methods have been suggested in order to evacuate air under the pea skin before the flotation grading process. Included among these methods have been water blanching, steam blanching, vacuum pumping, water aspirator, puncturing and water blanching, or skin removal (Walls and Hunter, 1938; Witebsky and Burr, 1951; Lee, Whitcombe and Hening, 1954; Holmquist et al., 1954; Makower, 1957; United States Department of Agriculture, 1959; Key Equipment Company, 1966; Mitchell, Lynch and Casimir, 1969; Mitchell, Casimir and Lynch, 1969). In early processing of peas, the blanching step was designed to follow the quality grading step (Bitting, 1909), but later the equipment models have been changed to set up the blanching step before doing quality grading (Martin, 1944; Havighorst, 1947; Key Equipment Company, 1966). Efficiency of water blanching of green peas is improved when the peas are punctured by using pins of 0.5 mm diameter before water blanching. The rate of gas elimination is greater, the separation of the peas by density in brine is more accurate, and can vacuum is increased. While acceptability of the canned peas is not lowered by puncturing process (Mitchell, Casimir and Lynch, 1969). For the quality control procedure, Witebsky and Burr (1951) treated the peas under vacuum by using a water aspirator and they found that the percent sinkers increased as vacuum was increased. They recommended the inclusion of a water aspirator step in routine quality control work, but Lee and Hicks (1965) commented that it was a little cumbersome. The United States Department of Agriculture (1959) specified that peas for brine flotation test should be thawed and the skins removed before the test to prevent errors caused by gas retention. Brine flotation tests are routinely conducted on graded peas after the skins have been removed in order to control the average maturity of the graded product and to indicate when changes in the density level of the salt brine in the quality grader are necessary (Mc Gowan, 1983).

Application of brine flotation principle in factory-grading system

The major advantages of quality grading peas by using brine flotation are greater uniformity and accuracy of pea maturity, less splits and skins, and a reduction in pea skin toughness due to extraction of calcium from the skin by salt brine (Shook, 1932). The first patent was granted on a device for grading peas in 1894 (Bitting, 1909; Albright, 1932). The others have been invented and improved both in mechanical devices themselves and steps of operation. In 1909, Bitting mentioned that the factory operations were vining or thrashing, washing, brine grading, hand picking, blanching, and canning respectively. Walls (1936) and also Stephens, Tucker and Griffiths (1966) suggested that the combination of density and sieve size in grading system gave the greatest accuracy for grading results. In 1944, Martin designed a cylindrical grading tank that separated peas into only two grades and the quality grader was placed after size grader and after blancher. Havighorst (1947) first published information about the improved quality separator that was called the Key Quality Grader, invented by Claude Key. By applying a brine jet system in this equipment, the turbulance effect at the brine surface was expected to be lower. Prior to 1966, further improvements were made in quality grader equipment. One development consisted of a top-opening rectangular separatory tank equipped with a taylor density controller, which helped the operator to adjust the brine density more easily than before (Key Equipment Company, 1966). In 1980, Rutledge and Board suggested that the tenderometer gave useful estimates for the maturity of raw peas but not of thawed or cooked ones. The adjustment of brine density in the Key Quality Grader

(1966) was based on the tenderometer reading for the raw peas, brine test results for quality control of separated peas, and operator's experience (Mc Gowan, 1983). The density of brine, used in the separatory tank, varies from 27-45 degree salometer in order to contend with the variation in pea maturity encountered during a single season. Present-day processing of peas places brine grading among a series of process steps including vining or thrashing, washing, grading for size, blanching, cooling, brine grading, washing, hand picking, and freezing or canning respectively (Mc Gowan, 1983).

Alcohol Insoluble Solids (AIS)

The Alcohol Insoluble Solids test is essentially a measure of the starch content of a starchy vegetable. Since sugars are converted to starch during the maturation process of these vegetables, AIS has been used as an index of maturity increase. Crude fiber, some proteins, salts, and certain other carbohydrates are also included in the AIS (Ottosson, 1958; National Canners Association Research Laboratories, 1968). The first method of analysis was devised by Kertesz in 1934 (Kertesz, 1934; Ottosson, 1958). Many experimentors believed that AIS of peas is best suited to the evaluation of maturity and quality of canned and frozen peas; so that AIS results are always used as the reference for many objective methods. AIS results show a high degree of correlation to the results of many objective methods of grading such as sensory evaluation (0.60-0.94), pea tenderometer (0.51-1.00), Christle texturometer (0.89 and 0.95), maturometer (0.91-0.98), specific gravity (0.74-0.99), and Kramer shear press (0.95-0.98) (Kertesz, 1934, 1935; Ottosson, 1958; Voisey and Nonnecke, 1973). Bonney and Rowe (1936) found that AIS was an excellent index of maturity for both Alaska and sweet peas but not for Minn 4 AM. Kertesz (1935) reported that AIS was a sensitive index of maturity measurement for green peas. This conclusion supported by Voisey and Nonnecke (1973), who compiled the range of AIS in peas reported by many experimentors from 1934 to 1969 and found that AIS had high overall range. AIS limits for each quality grade vary for different types and sizes of peas. In early type with sieve size 1 and 2, %AIS were up to 11.3 for Grade A, 11.4-14.4 for Grade B, and 14.5-23.5 for Grade C; sieve size 3, %AIS were up to 15.1 for Grade A, 15.2-18.5 for Grade B, 18.6-23.5 for Grade C, etc. While in sweet type with sieve size 2 and 3, %AIS were up to 9.8 for Grade A, 9.9-12.2 for Grade B, 12.3-21.0 for Grade C; sieve size 4, %AIS were 11.4 for Grade A, 11.5-14.2 for Grade B, 14.3-21.0 for Grade C, etc. (Gould, 1977). Immature peas of the Venus variety have 8.363 percent AIS, the mature ones have 11.555 percent AIS, and the overmature peas have 15.315 percent AIS (Olaeta-Coscorroza, 1980). The limitations of AIS analysis are that it is time-consuming, and that it is influenced by desiccation (Makower, 1950).

MATERIALS AND METHODS

Materials

Green peas (Pisum sativum) of the Dark Skin Perfection variety were obtained from the Stayton Canning Company plant, Brooks, Oregon in July, 1984. The peas were collected from three sampling points in the production line immediately before or after the brine flotation grader. The samplings provided three lots of peas for the study, as follows: (1) blanched but ungraded, (2) graded floaters and (3) graded sinkers. The peas were held under refrigeration at 1.1°C (34°F) for further analysis.

Methods

(a) Pea sampling method for flotation and quality control tests

The green peas were sampled from the factory production lots by using a 30 ml. beaker (volumetric sampling) in order to get about 55-65 peas per replication.

(b) Preparation of separation media

(b.1) Sodium chloride brine. Sodium chloride (Culinox food grade salt 999) was used to prepare 24, 34, 39 and 42 degree salometer salt brines respectively at room temperature (6.5%, 9.0%, 10.5% and 11.0% w/w). These brines were used in all flotation test conditions except for testing the effect of underskin air on the percent floater value. The 13% w/w concentration of brine was prepared for use in the quality control test..

(b.2) Sucrose syrup. 20% w/v sucrose syrup (36.5 degree salometer) was prepared at room temperature and 0.005% mercuric chloride was added as preservative (Witebsky and Burr, 1951). The syrup was prepared for the underskin air test on the peas and concentration was adjusted to approximate the mid-point density of the four salt brine solutions.

(c) Flotation test

The flotation test method was adapted from the United States Standards for Grades of Frozen Peas, 1959. Brine or syrup solution was filled into a 250 ml. glass beaker to a depth of approximately 2 inches (about 150 ml. solution). The peas were sampled by using method mentioned in (a) and were placed in the solution. Pieces of peas and loose skins were not counted in the brine flotation test. Only peas that sank to the bottom of the receptacle within 10 seconds after immersion were counted as "peas that sink" (United States

Department of Agriculture,1959). The floaters and sinkers at each condition were laid on the 8 mesh screen, sprayed with distilled water, and were drained on the tilted screen for 2 minutes. The drained floater and sinker fractions were collected in glass screw top jars and placed in -40°C frozen storage for AIS analysis. Ten replicate samples were analyzed for each condition. The test conditions are mentioned in the sublists of (c) below:

(c.1) Test of percent floaters at various brine concentrations. The brine concentrations used were 24, 34, 39, and 42 degree salometer at room temperature, 26°C. The peas were removed from the 1.1°C cold room and held in room temperature until their temperature was rather constant (24 °C).

(c.2) Test of percent floaters at various brine temperatures. The brine concentration used was 34 degree salometer at room temperature, 27.5 °C. The brine temperatures used were 5, 15, 27.5, and 41.5°C. The 250 ml. glass beakers, containing brine, were covered with aluminum foil and stored in 1.1°C (34°F) cold room in order to adjust the temperatures for 5, and 15°C testing conditions. In case of 41.5 °C, the covered beakers of brine were heated on a waterbath. The degree salometer of the brine solution was also checked at each brine temperature condition. The peas were removed from the 1.1 °C cold room and held in room temperature until their temperature was rather constant

(25.5°C).

(c.3) <u>Test of percent floaters at various pea temperatures</u>. Pea temperatures used were 3, 12, 25, 40, and 60 °C. Samples of peas for flotation test at the various temperatures were transfered into 50 ml glass beakers from the lots stored at 1.1 °C (34 °F). The samples were then placed in room temperature for sufficient time to reach the desired temperature for the test, or heated on waterbath for 40 and 60 °C test conditions. The 34 degree salometer test brine was used at room temperature (26°C).

(c.4) <u>Test of change in percent floaters according to underskin air</u>. The 20% w/v sucrose syrup was used as the separation medium. At this sucrose concentration, the specific gravity of this medium was equivalent to 36.5 degree salometer salt brine at room temperature (26.5°C). The pea temperature used was 26.5°C. The peas were tested for flotation by using the method mentioned in (c), and then were laid on 8 mesh screen, sprayed with distilled water, and drained on a tilted screen for 2 minutes. The sinkers from the test were skinned and collected for AIS analysis. Then, the floaters from the test were carefully skinned and retested for flotation by using the method mentioned in (c) again. The floaters and sinkers in the latter test were collected separately for AIS analysis.

(d) Quality control test

The efficiency of separation of field-run peas by the in-plant brine flotation grader was tested using pea samples drawn from the factory floater fraction and other peas from the factory sinker fraction. The peas were sampled by using method mentioned in (a). After the skins had been carefully removed, the peas were checked for flotation test mentioned in (c) by using 13% w/w NaCl solution as the separation medium (United States Department of Agriculture, 1959). The drained floater peas and sinker peas from each of the factory floater and sinker fractions were frozen in glass screw top jars at -40°C for later AIS analysis.

(e) Alcohol Insoluble Solids determination

The frozen pea samples, reserved from floater and sinker analyses, were defrosted in their glass containers. Then, the peas were poured on 8 mesh sieve, drained and rinsed with a volume of water equal to twice the capacity of the container from which the peas came. The peas were again drained for 2 minutes and the underside of the sieve was wiped free of moisture. Equal parts of peas and distilled water were weighed to an accuracy of 0.2 gm, and combined in an Osterizer blender cup. The peas and water were comminuted and stirred to a uniform mixture (National Canners Association Research Laboratories, 1968). Sample (10-15 gm.) was weighed to an accuracy of 0.001 gm. for three replicate samples and transferred to 250 ml. glass beakers. 150 ml. of 85% ethyl alcohol was added, and the mixture was stirred. The beakers were covered with watch glasses, brought to a boil, simmered slowly for exactly 30 minutes. The preparation of filter paper consisted of drying Whatman no.1 filter paper discs in a Petri dish (with opened cover) for 2 hours at 100°C, covering the dish with its cover, cooling it in a dessicator, and promptly weighing to an accuracy of 0.001 gm.. The samples were filtered by using the prepared filter paper and aspirator system. The precipitates were washed with 85% ethyl alcohol until the filtrates became colorless. The filter papers were transferred with the material retained thereon to the dishes used in preparing the filter papers. The materials were dried in a ventilated air oven for 2 hours at 100 °C with covers removed. The dishes were covered, cooled in a dessicator and promptly weighed to an accuracy of 0.001 gm.. The percent of alcohol insoluble solids was calculated by the equation:

% AIS = ((weight of dish + filter paper + materials) - (weight of dish + filter paper)) x 2 x 100 / (weight of sample used)

(Gould, 1977).

(f) Statistical methods

(f.1) Linear regression analysis. SIPS statistical program (Rowe and Brenne, 1982; OSU Computer center, 1983) was used to evaluate the results. Transformations and weighted least squares methods were investigated in order to get a high coefficient of determination, well-distributed residual plots, a low standard error of intercept and slope factor in the linear regression equation (Neter, Wasserman and Kutner, 1983).

(f.1.1) for effect of each condition on percent floaters. The simple linear regression with weighted least squares provided the best fit in case of brine concentration VS percent floaters, pea temperature VS percent floaters, and brine temperature VS percent floaters (Neter, Wasserman and Kutner, 1983, P.361).

(f.1.2) for effect of various conditions on percent floaters. Brine concentration (X1), brine temperature (X2), brine concentration x brine temperature (X1X2), pea temperature (X3), and skin-removal condition (Z = 0 = with skin, Z = 1 = without skin) were used as independent variables and percent floaters was used as the dependent variable for the multiple regression equation. Stepwise method was used as the technique in considering the importance of each independent variable to be included in the equation. No transformation was needed. The simple multiple regression with weighted least squares provided the best fit. Two independent variables, brine concentration and skin-removal condition, were dropped from the equation (Neter, Wasserman and Kutner, 1983).

(f.1.3) <u>for effect of each condition on percent Alcohol Insoluble Solids of floaters and sinkers</u>. Three replicate results of percent AIS were averaged and used in this part of evaluation. Percent AIS was transformed to the reciprocal, and the reciprocals were used as dependent variables for simple linear regression equations in case of brine concentration VS percent AIS of floaters, brine concentration VS percent AIS of sinkers, pea temperature VS percent AIS of floaters, and pea temperature VS percent AIS of sinkers. The simple linear regression with no transformation was well-fitted for brine temperature VS percent AIS of floaters and brine temperature VS percent AIS of sinkers (Neter, Wasserman and Kutner, 1983).

(f.2) <u>Least Significant Difference</u>. The Least Significant Difference (LSD) was used to evaluate the significance of changes in percent floaters with respect to changes in brine temperature, pea temperature, or brine concentration. The models for these experiments were Completely Randomized Design, and LSD at 95% and 99% confidence were calculated (Snedecor and Cochran, 1980). In case of skin removal, a paired sample comparison test (Snedecor and Cochran, 1980) was used to test the significance of changes in percent floaters at both degrees of confidence.

(f.3) Correlation Coefficient. The correlation coefficient between the means of percent floaters at each condition, and the mean percent AIS of their floaters and sinkers at those conditions were calculated by assuming that both variables were independent (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Brine flotation test of processor-graded peas

Peas obtained at the processing factory had been water-blanched and graded for maturity in a brine-flotation quality grader. The sample of floater peas selected from the processing line was designated as U.S. Fancy maturity grade by the processor. The results of a standard USDA brine flotation test conducted on the floater sample (Table 1) confirmed that the percentage by count of peas which sank in a 13% w/w sodium chloride was within the 10% tolerance for a U.S. Fancy grade of frozen peas. However the sinker sample from the processing factory was shown to contain a significant percent of peas which floated when subjected to the same 13% brine flotation test, and could be considered U.S. Fancy grade for maturity. These floater peas in the sinker fraction tested higher in AIS than the floater fraction but much lower in AIS than the mean for the sinker fraction (Table 2). These findings illustrate a problem faced by the pea processor who often finds some peas of floater maturity being lost in the sinker fraction.

Test of percent floaters at various brine concentrations

It was found that the percent floaters increased as the

Table 1: Quality control test using 13% w/w sodium chloride salt brine

Sample	% Floaters[1]	% Sinkers[1]
Floater fraction from the factory	97.9	2.1
Sinker fraction from the factory	44.9	55.1

[1]Percentage by count

Table 2: Alcohol insoluble solids (AIS) of factory-graded peas (skin removed)

Sample	% AIS[1]
Fancy grade floater fraction (factory)	11.85
Floaters from factory-sinker fraction in 13% w/w salt brine	12.75
Sinker fraction from the factory	19.24

[1]Means of three replicate analyses on a single blended pea sample

brine concentration increased (Figure 1). An increase of sodium chloride concentration produced an increase in the specific gravity of the separation media (Weast, 1983). The coefficient of correlation between brine concentration and percent floaters was high (0.96), and the rate of increase in percent floaters was shown by the equation in Figure 1. In an LSD test, it was shown that the mean percent floaters increased significantly ($p \leq 0.01$) at each of four increments of sodium chloride brine concentration between 24 and 42 °salometer was significantly ($p \leq 0.01$) (Table 3). Percent AIS in both floaters and sinkers increased as the brine concentration increased. Furthermore, the correlation coefficients between percent floaters and percent AIS of floaters and sinkers were positive and high (Table 3). As the percent of floaters increased with the upward adjustment of the brine, the probability that more mature quality peas would enter the floater fraction increased also. This supposition was confirmed by the percent AIS results obtained after each rise in brine concentration (Table 3). As the sinker fraction was reduced (the number of floaters increased), the probability that the lower maturity , higher quality peas would be removed from the sinker fraction increased too. This trend is indicated by the increase in percent AIS shown for sinker peas in Table 3. The rates of increase in percent AIS for both fractions as brine concentration was changed, are shown as fitted regression

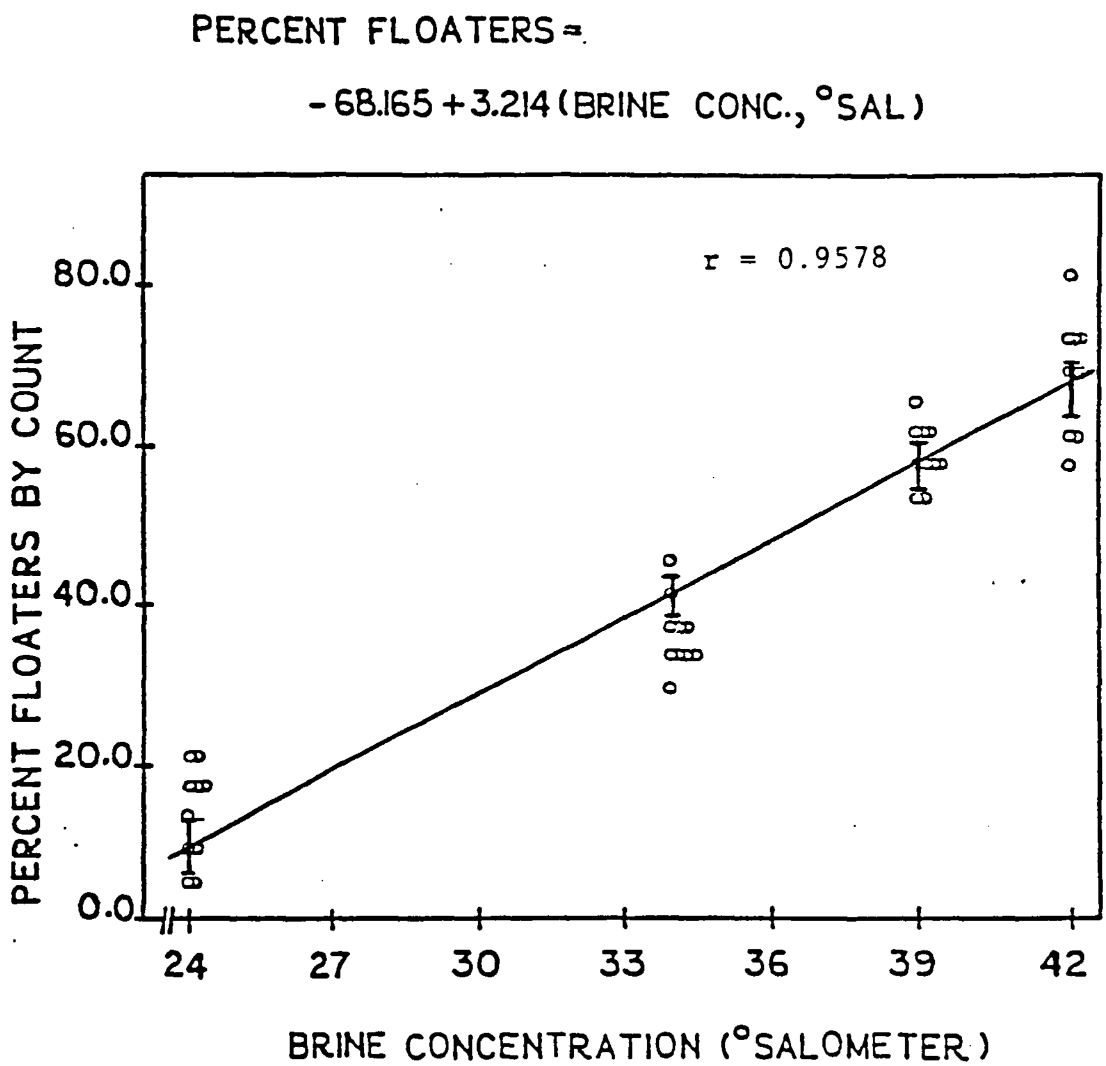

Figure 1: Scatter plot and regression of percent floater peas in factory-blanched ungraded peas on brine concentration (standard error limits shown)

Table 3: The effect of brine concentration on percent floaters; correlation coefficients of percent floaters with percent AIS of floaters, and with percent AIS of sinkers

Quality	°Salometer				Correlation
Parameter	24	34	39	42	coefficient[3]
% Floaters[1]	12.4a	35.1b	57.9c	68.0d	-
% AIS of floaters[2]	11.51	11.65	12.10	12.53	0.910
% AIS of sinkers[2]	15.30	15.70	17.73	18.50	0.927

[1]Means of 10 replications. Values at each brine concentration are significantly different at p = 0.01 if followed by different letters

[2]Means of 3 replicate analyses on a single blended pea sample

[3]Correlation coefficients between percent floaters and each of the other quality parameters (n = 4 pairs)

(1/PERCENT AIS OF FLOATERS)=

0.097 -0.0004 (BRINE CONC.,°SAL.)

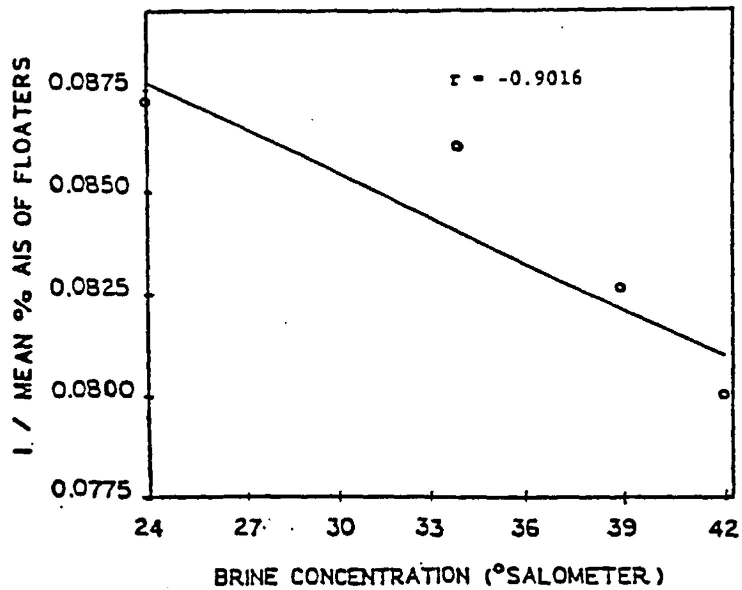

Figure 2: Regression of reciprocal of mean percent AIS of floater peas on brine concentration

(1/PERCENT AIS OF SINKERS)=

0.082-0.0006 (BRINE CONC.,°SAL.)

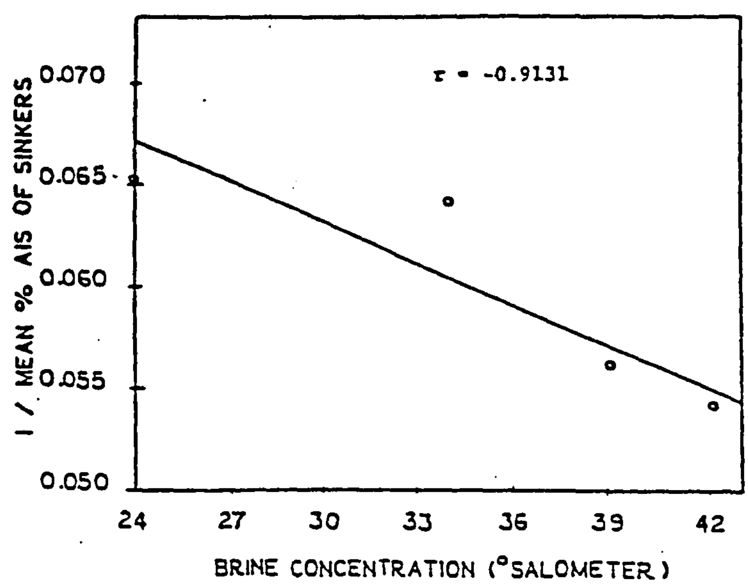

Figure 3: Regression of reciprocal of mean percent AIS of sinker peas on brine concentration

lines and equations in Figures 2 and 3 (Transformation of the AIS values to their reciprocals was carried out before the regression analysis in order to maximize the coefficients of correlation).

Test of percent floaters at various brine temperatures

The effect of changing brine temperature on the percent output of floater peas in the brine grading operation is shown in Figure 4. A high negative correlation ($r = -0.94$) was obtained between these variables, indicating that when the brine temperature was increased, the percent floaters decreased. The rate of change can be determined from the regression equation, also shown in Figure 4. The reason for the lowered buoyancy of the peas when the brine temperature is increased can be related to the rule that density of a liquid changes when its temperature changes (Tabor, 1969). Confirmation of this rule can be seen in Table 4, where the degree salometer of salt brine decreased when the temperature was increased.

The percent floaters decreased significantly ($p \leq 0.01$) for each increment of increase in brine temperature (Table 5). Percent AIS in both floaters and sinkers decreased as the brine temperature was increased and it was also found that a very high correlation existed between percent floaters and percent AIS of floaters and sinkers

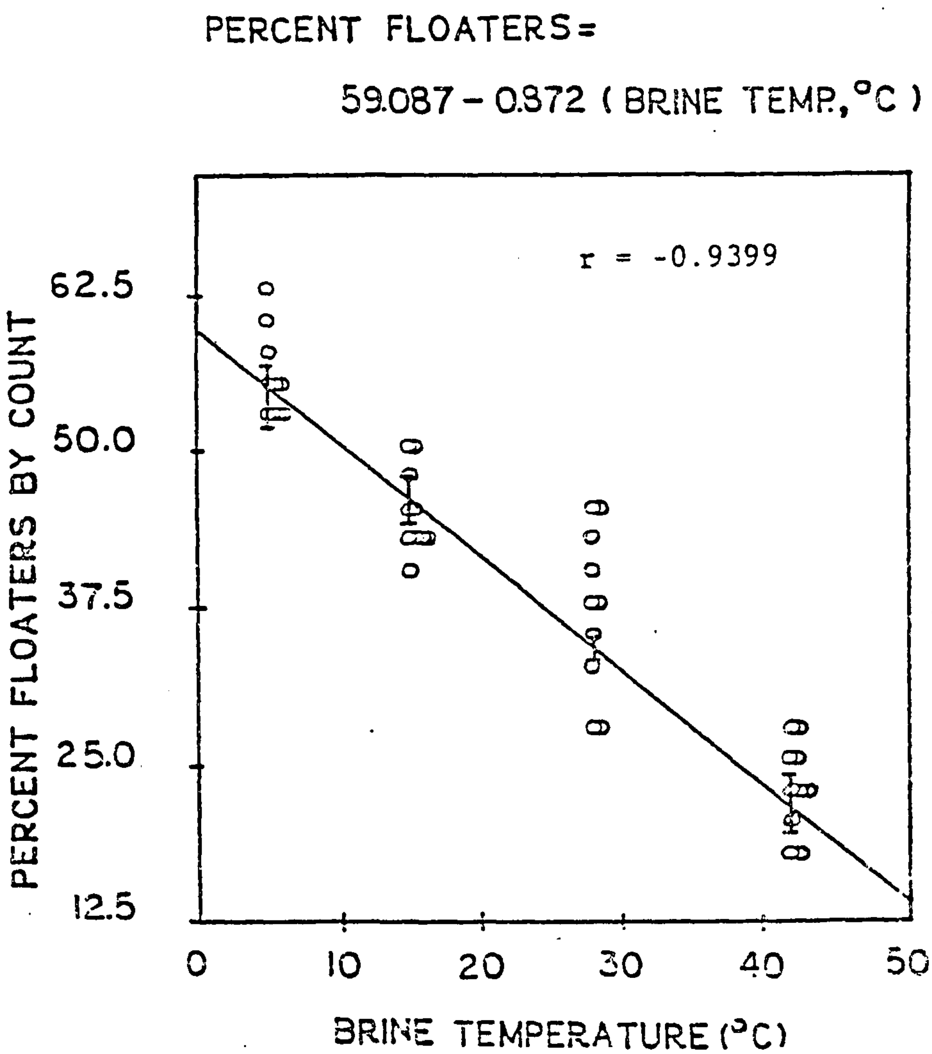

Figure 4: Scatter plot and regression of percent floater peas in factory-blanched ungraded peas on brine temperature (standard error limits shown)

Table 4: Degree salometer of 9.0% w/w sodium chloride salt brine at various temperatures

Temperature (°C)	°Salometer
5.0	38.0
7.5	37.0
15.0	36.0
18.0	36.0
20.0	35.5
27.5	34.0
41.5	32.0

Table 5: The effect of brine temperature on percent floaters; correlation coefficients of percent floaters with percent AIS of floaters, and with percent AIS of sinkers

Quality Parameter	Brine temperature (°C) 5	15	27.5	41.5	Correlation coefficient[3]
% Floaters[1]	55.4a	44.4b	37.0c	22.9d	-
% AIS of floaters[2]	11.80	11.76	11.73	11.55	0.961
% AIS of sinkers[2]	17.06	16.48	16.15	15.50	0.968

[1]Means of 10 replications. Values at each brine temperature are significantly different at $p = 0.01$ if followed by different letters

[2]Means of 3 replicate analyses on a single blended pea sample

[3]Correlation coefficients between percent floaters and each of the other quality parameters ($n = 4$ pairs)

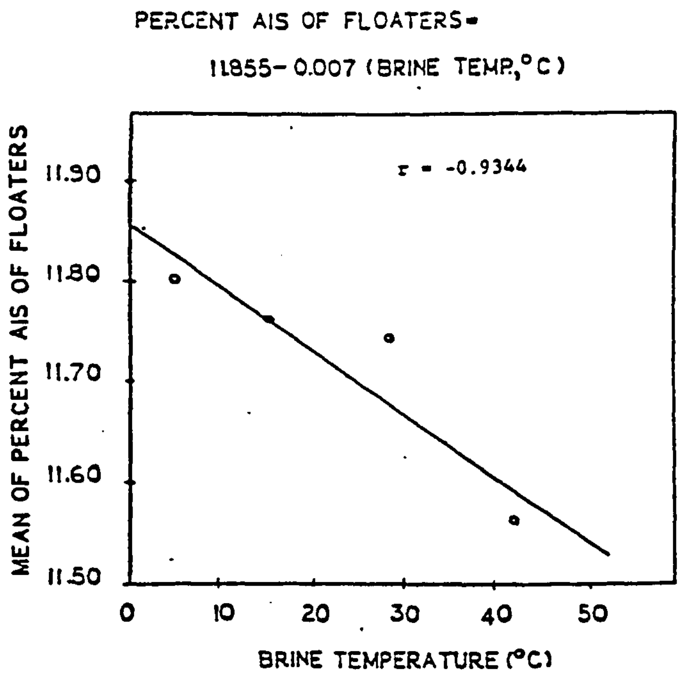

Figure 5: Regression of mean percent AIS of floater peas on brine temperature

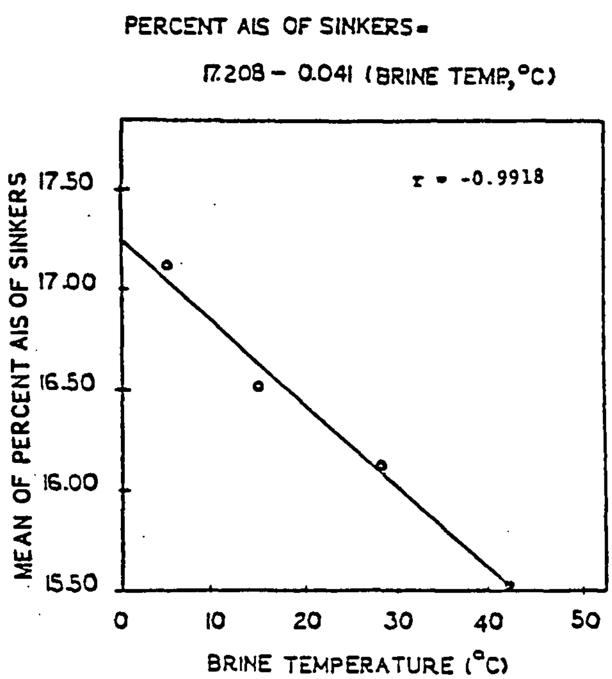

Figure 6: Regression of mean percent AIS of sinker peas on brine temperature

(Table 5). As brine temperature increased, the number of floaters, and % AIS of the floaters decreased since the more mature peas in the floater fraction had the highest probability of sinking. Conversely, when the number of sinkers increased, the probability of dropping more lower maturity peas into the sinker fraction increased, so percent AIS decreased. The rates of decrease in percent AIS in both fractions, as brine temperatures were increased, are shown as fitted regression lines and equations in Figures 5 and 6.

Test of percent floaters at various pea temperatures

As the temperature of the peas during grading was increased, percent floaters also increased. The rate of floater increase, derived from the slope of the regression equation in Figure 7, and the coefficient of correlation ($r = 0.83$) were both lower than corresponding values for the other variables studied. The increase in percent floaters with increasing pea temperature has been attributed by other researchers to a small decrease in density of peas related to thermal expansion (Kingsbury, 1965; Resnick and Halliday, 1968; Tabor, 1969). The current results suggest that pea temperatures have a lesser effect on percent floaters since the rate of change (slope) was low compared with the same statistic for the other factors studied (Figure 7, Figure 1, Figure 4). Furthermore, there were not significant

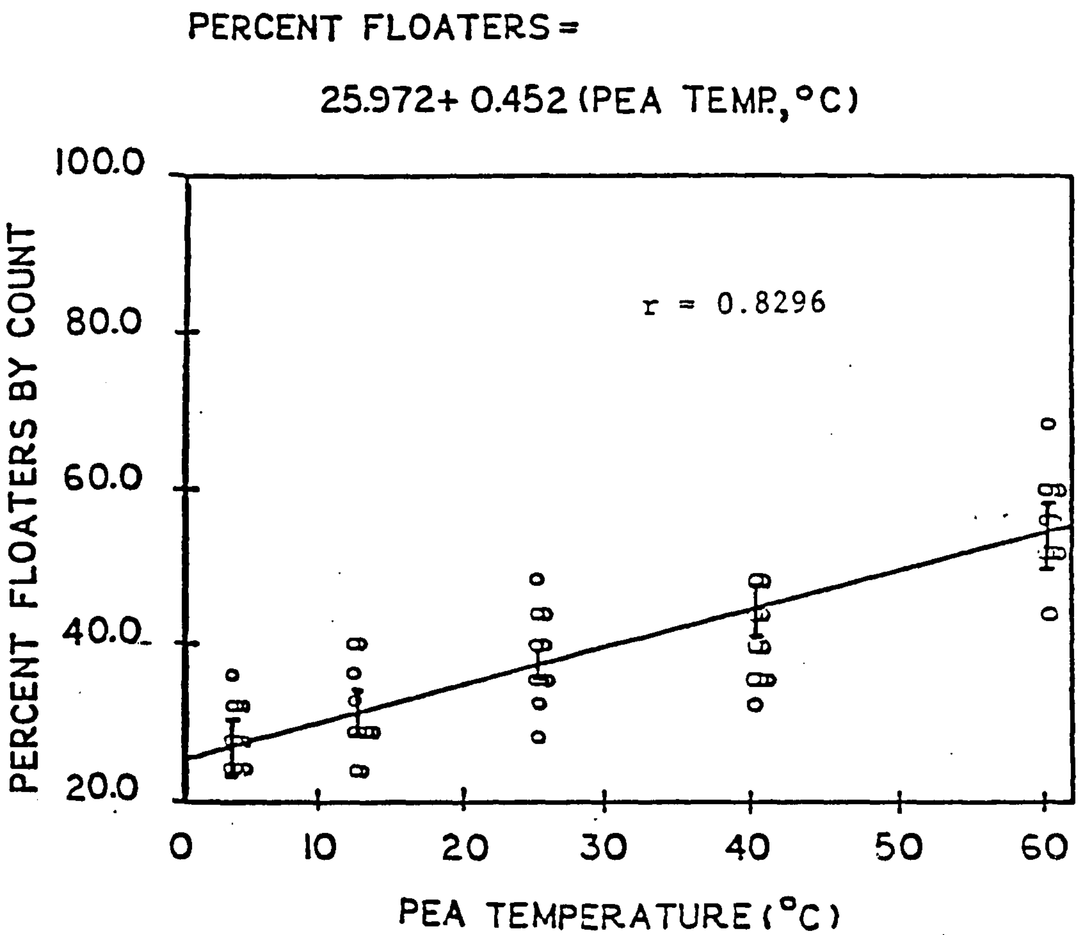

Figure 7: Scatter plot and regression of percent floater peas in factory-blanched ungraded peas on pea temperature (standard error limits shown)

Table 6: The effect of pea temperature on percent floaters; correlation coefficients of percent floaters with percent AIS of floaters, and with percent AIS of sinkers

Quality Parameter	Pea temperature (°C) 3	12	25	40	60	Correlation coefficient[3]
% Floaters[1]	29.1a	31.0a	38.1b	40.0b	55.4c	-
% AIS of floaters[2]	11.51	11.80	11.79	11.93	12.39	0.977
% AIS of sinkers[2]	15.28	16.01	16.09	16.27	17.64	0.982

[1]Means of 10 replications. Values at each pea temperature are significantly different at $p \leq 0.05$ if followed by different letters

[2]Means of 3 replicate analyses on a single blended pea sample

[3]Correlation coefficients between percent floaters and each of the other quality parameters (n = 5 pairs)

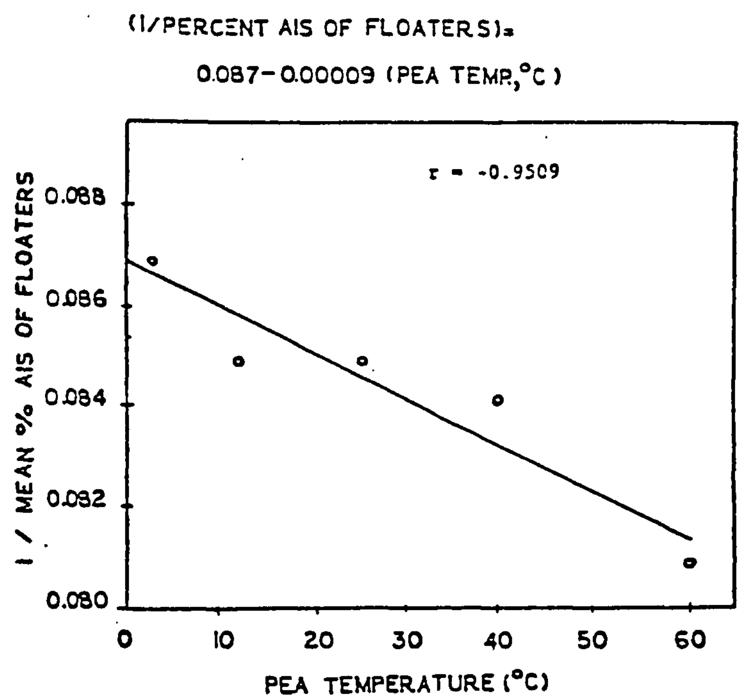

Figure 8: Regression of reciprocal of mean percent AIS of floater peas on pea temperature

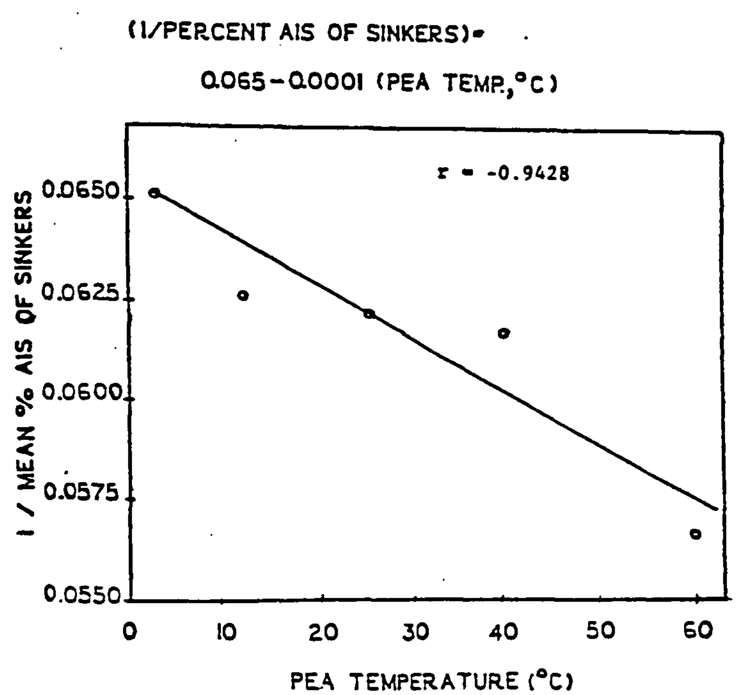

Figure 9: Regression of reciprocal of mean percent AIS of sinker peas on pea temperature

differences in % floaters across some ranges of pea temperatures selected, such as between 3 °C and 12°C, or between 25°C and 40°C. There were significant differences ($p \leq 0.05$) in % floaters across the other temperature ranges (Table 6). Percent AIS in both floaters and sinkers increased as the pea temperature increased and the correlation coefficients between percent floaters and percent AIS of floaters and sinkers were positive and high (Table 6). The cause of an increase in percent AIS as the pea temperature was increased could be explained by the same reason given for change in percent floaters at various brine concentrations result. The rate of increase in percent AIS in both fractions (floater and sinker) as pea temperature was changed, was derived from the regression lines and equations in Figures 8 and 9. Percent AIS were transformed to their reciprocals before the regression analysis in order to get higher coefficients of correlation.

Test of underskin air and effect on percent floaters

As reported in Table 7, a highly significant decrease ($p \leq 0.01$) in percent floaters occurred after the peas had skins removed. The cause of this change in floater percentage appears to be an increase in pea densities when accumulated gases under the pea skin are lost by skin removal. Mitchell, Casimir and Lynch (1969) commented that

Table 7: Effect of pea skin removal on percent floaters

Condition	Mean[1]
Peas with skin, % floaters	53.9a
Peas without skin, % floaters	49.2b

[1]Means followed by different letters are significantly different at $p = 0.01$

Table 8: Percent AIS of peas following pea skin removal condition

Condition	% AIS[2]
Floaters[1]	10.93
Floaters with skins but sink without skins	15.82
Sinkers[1]	18.21

[1]Pea skin removed

[2]Means of 3 replicate analyses on a single blended pea sample

water blanching could not evacuate underskin air completely. The percent AIS of pea floaters, which sank after they had their skins removed, was intermediate between floater's and sinker's (Table 8). It can be concluded that the peas which should be most affected by underskin air were borderline in density and their maturity was between that of most floaters and sinkers.

Selection of major tested factors affecting percent floaters

Using stepwise regression technique, the factors in the study selected as most influential on the density separation of peas were brine concentration, brine temperature, and pea temperature. The underskin air factor was found least important and was dropped. The composite effects of those factors on percent floaters was shown as an equation:

Percent floaters = 41.370 - 4.633 (brine temperature, ^{o}C) + 0.439 (pea temperature, ^{o}C) + 0.122 (brine concentration, ^{o}Salometer) x (brine temperature, ^{o}C)

with the coefficient of multiple determination (R squared) = 0.8884. Compared with other factors, underskin air is shown in the regression to have a minor effect on percent floaters.

SUMMARY AND CONCLUSIONS

The maturity quality of blanched peas from factory brine-graded fancy floater and sinker lots were determined, using the brine flotation test, as prescribed in the United States Standards for Grades of Frozen Peas (1959). The test showed that there was a high percent of floater peas (regarded as higher quality and higher price) present in the commercial-graded sinker fraction (regarded as lower quality and lower price). These results illustrate that incomplete maturity separation of peas continues to be an economic problem of pea processors.

Four variables of the brine flotation quality grading process - brine concentration, brine temperature, pea temperature, and underskin air - were studied to determine their effects on the efficiency of the quality grading process. Based upon regression analysis and slopes of fitted regression lines, brine concentration was the most critical factor in affecting a change in percent floaters, while pea temperature was the least effective. An increase in brine concentration or pea temperature increased percent floaters, while an increase in brine temperature decreased percent floaters. The study showed that residual underskin air in the intact blanched peas affected the accurate separation by a false increase in buoyancy of border line maturity peas in the flotation process and that water blanching was not completely able to solve this problem. 4 factors individually studied, had a significant effect on the % floater value. The causes of these changes were because of the changes in densities of brine as its temperature or concentration was changed, or of peas as their temperature was changed or the underskin air was removed by deskinning of the peas.

Changes in percent floater peas affected by the flotation variables tested in this study were highly and positively correlated (r = 0.961 - 0.982) with the mean maturity of the floater fraction and sinker fraction as determined by Alcohol Insoluble Solids analysis.

Using stepwise multiple regression statistics, it was shown that brine concentration, brine temperature, and pea temperature were each significant factors affecting change in percent floater peas in the brine flotation grading system. Underskin air retention was shown to be of less importance in the multiple regression analysis.

The factors included in this study were only the ones that could be studied in the laboratory and mentioned to be major causes for inaccurate commercial grading as reported in some of the literature. Commercial application of these results is not recommended now. Some other factors such as turbulance effect of brine in the separation process, overload of peas in the grader are needed to be studied in the commercial separation plant. It is recommended that future studies should include the cost benefit analysis of alternative methods, since economic considerations may be equally important to a system improvement study.

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