AN EVALUATION OF CONSUMER ACCEPTANCE OF EGGS HAVING MOTTLED YOLKS

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CHARLES JERRY COX

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John H. Wolford
Major professor

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ABSTRACT

AN EVALUATION OF CONSUMER ACCEPTANCE OF EGGS HAVING MOTTLED YOLKS

by Charles Jerry Cox

Egg yolk mottling is often a serious economic problem to the poultry industry as eggs having mottled yolks are downgraded in quality. Eggs produced by most laying flocks have a limited amount of "natural" mottling. The intensity of natural mottling is apparently low. Most poultrymen believe it is seldom serious enough to cause consumer complaints.

This investigation was concerned with consumer acceptance of eggs having mottled yolks and consumer reaction to varying degrees of mottling. The level or degree of mottling at which consumers reject eggs and the effect of various demographic factors such as age, education, income and geographic location on consumer preference for mottled yolks was analyzed.

Consumer preference data were collected through the use of consumer panels. Consumer preference panels were conducted in Detroit, Michigan and Athens, Georgia. These panels were designed to determine preferences of consumers with annual incomes ranging from under $2,000

to over $10,000, of ages from under 30 years to over 60 years, and with 0 to 14 years of formal education. A paired-comparison test was used whereby each untrained panel member was presented two coded samples and asked to compare them.

A six-point scale was used to assess the degree of mottling with each point representing a different degree of mottling. The method of paired-comparisons employing unequal repetition of pairs was used to determine overall preference of samples.

The data collected indicate that consumers do not notice mottling at low levels and that "natural" mottling is not usually severe enough for most consumers to notice. Moderate mottling covering five to fifteen percent of the exposed yolk surface, was found to be the breaking point for consumer acceptance of eggs having mottled yolks. Mottling above this level was found to be objectionable to consumers.

Analysis of various demographic factors such as age, education, income and location revealed that these factors had relatively little influence on consumer preference for eggs having mottled yolks. Although some differences were found, the amount of variation was too small to be statistically significant.

Based on the results obtained in these studies, it is recommended that the United States Standards for Quality of Individual Eggs be revised to include yolk mottling in quality determination. Since consumers apparently do not reject eggs with slight and moderate yolk mottling, this level or degree of mottling should be permitted in the U.S.D.A. Grade AA and Grade A classification. Mottling covering from 15 to 60 percent of the exposed yolk surface should be classified as U.S.D.A. Grade B while mottling covering 60 to 100 percent of the yolk surface should be classified as U.S.D.A. Grade C.

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INTRODUCTION

Egg yolk mottling is often a serious economic problem to poultrymen and a corresponding inconvenience and loss to egg processors as eggs having mottled yolks are downgraded by egg buyers. Recent yolk discoloration or mottling has caused concern and even great financial losses to many poultrymen. This condition, although not new, is receiving renewed attention because most consumers find eggs having severely mottled yolks to be objectionable. Many housewives feel that severely mottled eggs represent low quality and spoilage even though there is no evidence to indicate that the egg is nutritionally or functionally affected by mottling.

Broken out eggs with mottled yolks appear to have spots or blotches of different colors or shades of color. These blemishes usually vary in size and amount. Some yolks have only a few small whitish-yellow "curdled" areas. Others have larger blemishes that may be brownish-orange with a streaked appearance.

Mottling appears to be caused by a movement of egg-white protein and water from the albumen or white of the egg through the vitelline membrane (membrane that encloses the yolk) into the yolk. This usually causes the

yolk to appear slightly larger. Mottled yolks contain more water, more egg white protein and a higher protein fat ratio than yolks free of mottling.

Dark colored yolks in eggs were first reported in 1891 as a condition produced by hens being fed cottonseed meal (Roberts and Rice, 1890-91). A limited amount of so called "natural" yolk mottling occurs in most laying flocks. "Natural" mottling usually occurs at low level incidence but it is seldom serious enough to cause consumer complaint.

Since the intensity of "natural" mottling appears to be relatively low, most poultrymen believe it is seldom serious enough to cause marketing problems. Very little information, however, is available on consumers' reactions to mottled eggs. The purpose of this study was to ascertain if "natural" mottling was objectionable and to determine at what level or degree of mottling the consumer rejects eggs having mottled yolks.

LITERATURE REVIEW

Yolk mottling was found in eggs from all flocks examined by Blackshear et al. (1967b). Of the eggs examined, 56.1 percent had some degree of mottling. Known causes of mottling include certain worming compounds (Beane et al., 1965), gossypol (Heywang et al., 1955), and Nicarbazin (Polin and Porter, 1956; Baker et al., 1957; Weiss, 1957). However, mottled yolks have been reported to occur in eggs when hens have been known to have no access to any of these compounds (Fry and Wilson, 1965; Polin et al., 1957).

A search of the literature brings forth considerable data on cause, effect and remedy of egg yolk discolorations called mottling.

Causes of Mottling

Dark colored yolks in eggs were first reported by Roberts and Rice (1891) who suggested that this condition was produced by hens fed cottonseed meal. Almquist (1933) also observed mottled yolks in eggs from hens fed cottonseed meal in their diets. Yolks from newly-laid eggs appeared normal, but the incidence and degree of mottling increased during storage. Mottled yolks contained more

water, more egg white protein and a higher protein-fat ratio than yolks free of mottling. It was concluded that mottled yolks were caused by diffusion of egg white protein into the yolk because the vitelline membrane was more permeable than in eggs free of yolk mottling.

Cottonseed meal and cottonseed oil, when fed to laying hens, can cause a deterioration in egg quality. A literature review on this subject showed that the following abnormalities are typical: Yolks are frequently mottled, of gelatinous consistency and enlarged; yolk color may be olive green, almost black or reddish; and the egg white may be pink or red in color. These abnormalties are generally accentuated by storage of the eggs. One of the major substances present in cottonseed products which contributes to the deterioration of egg quality is gossypol although other substances have also been implicated. Investigations of such substances and their mode of action has been a continuing field of research (Heywang, et al., 1955).

Schaible et al. (1934) were apparently the first to present comprehensive data showing that gossypol, found in the pigment glands of cottonseed is the component that causes dark yolk discolorations when cottonseed meal is fed to laying chickens. That the discolorations may range from light-brown to black was reported by Swenson et al. (1942) and Heywang et al. (1949). Lorenz

(1939) found that "reddish-brown" colored whites in eggs from layers fed cottonseed meal were attributable to a component in the lipids of cottonseed.

Schaible et al. (1936) observed a mottled yolk condition apparently similar to that described by Almquist (1933), but the mottled areas of the egg yolks were not caused by feeding cottonseed meal in the diet of hens. They found that a mottled area could be produced by slight mechanical pressure of the yolk membrane.

Cottonseed and its by-products have been implicated in the discoloration of eggs in two ways: (1) gossypol produced olive or chocolate-brown yolks described by Schaible et al. (1933) and Swensen et al. (1942) and (2) salmon colored yolks and pink whites associated with cottonseed meal feeding as reported by Sherwood (1928, 1931).

Kemmerer et al. (1963) found that 0.2 percent or more cottonseed oil in the diet and 3 milligrams per day or more of gossypol resulted in discoloration of stored eggs, but 0.1 percent cottonseed oil fed with 3 milligrams per day of gossypol did not result in discolored eggs.

The results of studies by Heywang et al. (1963) showed that only slight discolorations appeared in relatively few eggs after six months storage when pullets were fed cottonseed meal to furnish as much as 0.008 percent free

gossypol in their diet during the first 16 to 18 weeks of their life. These results are in agreement with those in a previous experiment by Heywang and Lowe (1959) in which a ten day period after removal of cottonseed meal from the diet of layers was sufficient to completely eliminate the occurrence of discolorations in their eggs.

The effect of pH on the development of "cottonseed" eggs was reported by Thompson et al. (1930-32). They showed that the yolk pH approaches the pH of the albumen more rapidly in hens fed cottonseed meal than in eggs from control hens. The recent reports of Kemmerer et al. (1961) and Frampton et al. (1961) showed that the dark discolorations caused by gossypol and those appearing in the yolks of stored eggs from layers fed cottonseed meal were accompanied by an increase in the pH of the yolks.

It is common knowledge that there is a loss of carbon dioxide from eggs during storage and that spraying their shells with oil or dipping them in oil will prevent or lessen the loss. This, in turn, should hold the yolk at a lower pH and, thus, lessen the dark discolorations. Heywang et al. (1962) reported that oiling the shells of fresh eggs decreased the formation of dark yolk discolorations during their storage.

Sherwood (1931) reported on the feeding of cottonseed meal to laying hens to produce pink albumens. Discoloration of egg albumen with the feeding of cottonseed

meal to hens was found to be due to the passage of iron from the yolk into the white, followed by a reaction with conalbumen causing a pink discoloration of the albumen. Passage of conalbumen into the yolk where it reacts with the yolk iron to give a pink color, which when blended with the normal yolk pigment apparently causes the salmon yolk color (Schaible and Bandemer, 1946 a.).

Lorenz (1939) stated that the causative agent of yolk discoloration was related to Halphen reactive substances in malvaceous plants. The pink discoloration agent was subsequently found to be present to raw cottonseed meal, cottonseed pigment glands, and in crude cottonseed oil, but not in cottonseed hulls (Heywang et al., 1954). Evans et al. (1957) reported ten years' work on the occurrence of pink whites and salmon yolks with the feeding of crude cottonseed oil or cottonseed meal and found the pink white factor to be labile. Masson et al. (1957) showed that the feeding of sterculic acid caused pink whites and salmon yolks in stored eggs. Malvalic acid produced typical pink-white discolorations in eggs from hens fed doses of 25 milligrams per day (Shenstone and Vickery, 1959). The failure of epoxy and hydroxy fatty acids to cause egg discolorations when fed to laying hens was demonstrated by Evans et al. (1965). Deutschman et al. (1961) studied the effect of hydrogen chloride and

sulfur dioxide treatments of sterculic acid and cottonseed meal on egg discolorations and found that treatment of cottonseed meal with sulfur dioxide appeared to destroy both the pink-white discoloring capacity and the olive yolk effect of cottonseed meal. The use of hydrochloric acid for the treatment of the cottonseed meal likewise prevented both pink whites and gossypol discolored yolks in eggs stored for six months. The treatment of Sterculia foetida oil, containing sterculic acid, with either hydrogen chloride or sulfur dioxide gas destroyed the Halphen reactivity of the oil and eliminated the development of pink whites in stored eggs from hens fed these materials.

An experiment was conducted by Pepper et al. (1962) to study the effects of the dietary inclusion of cottonseed oil, acidulated cottonseed soap stocks and cottonseed still bottoms on the interior quality of eggs stored at either 30° or 60°F. These researchers concluded, based on their data, that it would seem unwise to incorporate any of these three products into diets of laying hens.

Strains of cotton with seeds virtually free of pigment glands have recently been developed. It was postulated by Heywang and VaVich (1965) that meals prepared from such seed would not cause dark yolk discolorations, especially if the meals were low in lipids. Results

revealed, however, that commercial hexane treatment of these cottonseed meals did not remove all components that cause pink whites. It is probable that these processed meals contained "bound" lipids that were not removed by hexane extraction. Halloran and Cavanaugh (1960) showed that there was little correlation between free gossypol and available gossypol units and, therefore, concluded that the so-called degossypolized meal was not necessarily safe for inclusion in laying rations.

In an attempt to obtain a satisfactory commercial cottonseed meal, a series of screw pressed meals which contain very low levels of free gossypol have been developed. Stephenson and Smith (1952) found that the screw pressed cottonseed meal was satisfactory for incorporating in a poultry laying ration as the principle source of protein. The storage quality of eggs produced from hens fed the screw pressed cottonseed meal was similar to those obtained from hens receiving soybean oil meal as the principle protein supplement.

Kuiken et al. (1948) prepared an isopropanol extracted cottonseed meal which when fed at a level of 20 percent of the total ration did not affect the quality of eggs stored for six months. They demonstrated that free gossypol apparently caused no discoloration. Halloran and Cavanaugh (1960) indicated that properly treated and processed cottonseed meal can be included in hen laying rations

at least up to 10 percent of the diet.

Evans et al. (1960) found that no egg discoloration occurred when crude cottonseed oils heated to 200°C for eight hours or 240°C for one hour were fed.

Heywang (1957) presented data indicating that 0.25 percent and 0.5 percent ferric sulfate inactivated some of the free gossypol.

Nicarbazin, a coccidiostat introduced in 1954, was shown to adversely influence hatchability, thus was not recommended for adult chickens (Polin et al., 1956a). Within two years after inclusion of Nicarbazin in broiler rations the presence of mottled yolks in eggs from hens fed Nicarbazin was discovered and reported by Polin et al. (1956b).

Polin et al. (1957) concluded that the accidental feeding of Nicarbazin to layers might result from (1) erroneous use of starter, broiler or grower feeds which contained Nicarbazin, or (2) through contamination of layer rations with such feeds. Although mottled yolks did occur in eggs even when the hens had not received Nicarbazin in the ration, no significant increase in the occurrence of mottled yolks was shown until the level of Nicarbazin in the ration was increased to a minimum of 0.005 percent. Polin and Porter (1956) found similar results and reported further that when levels as high

as 0.03 percent Nicarbazin were fed, a direct relationship was found between degree of mottling and the percentage of Nicarbazin in the ration.

Polin et al. (1956a) developed a method of analysis for 4-4'--dinitrocarbonilide (DNC), the active ingredient in Nicarbazin, in the yolks of eggs. The rate at which DNC was deposited in the eggs of hens fed Nicarbazin depended upon the concentration of the compound in the blood and tissues and upon the rate of yolk deposition.

Weiss (1957) showed that Nicarbazin fed at a level of 0.0125 percent for ten to fifteen days to small groups of White Rock and White Leghorn pullets and to hybrid hens caused a "whitening of the tinted eggs," after three days' treatment. Egg production was reduced an average of 8.0 percent and egg weight an average of 5.0 percent. Shell thickness and albumen scores were not affected. One out of nine White Leghorn hens fed Nicarbazin laid fresh eggs with severely mottled yolks.

Polin et al. (1958) reported that 0.007 percent Nicarbazin in the ration of laying hens decreased egg size, by reducing the yolk size. When eggs from hens fed a minimum of 0.005 percent Nicarbazin were stored for seven to ten days, significantly more mottled yolks were found than in the control eggs. Extremely mottled yolks were associated with lower albumen quality, but no effect in

albumen quality was evident in eggs which were only slightly mottled.

Baker et al. (1957) reported that laying hens fed Nicarbazin produced eggs with "blemished" or mottled yolks. When a level of 0.0125 percent Nicarbazin was fed, nearly all of the eggs were severely mottled. At lower levels of Nicarbazin (0.006 to 0.009 percent) only a few severely mottled yolks were observed and only a minimum of 0.0015 percent Nicarbazin was required to increase the incidence of severely mottled yolks from hens fed 0.006 percent Nicarbazin in the ration. Egg production was reduced markedly by feeding 0.0125 percent Nicarbazin to Leghorns and 0.007 percent Nicarbazin to heavy breed hens. Egg size was also reduced by feeding a minimum of 0.006 percent Nicarbazin in the diet. The heavy breeds produced white-shelled eggs when fed 0.009 percent Nicarbazin while a level of 0.003 percent had no effect on shell color, but produced some mottled yolks.

The results of McLoughlin et al. (1957) agree with those of Weiss (1957) and Baker et al. (1957) in that heavy breed hens laid white-shelled eggs after the hens had been fed 0.0125 percent Nicarbazin for three days. During the second week of treatment, hens fed Nicarbazin laid only one-half as many eggs as the controls. This difference in egg production was maintained for more than

a week after Nicarbazin feeding was discontinued. No significant differences were reported in egg weight, shell thickness or interior quality of eggs between those produced by hens fed a control ration and hens fed Nicarbazin.

Three general observations concerning mottled yolks which Baker et al. (1956), Polin (1957) and Van Tienhoven et al. (1958) have reported are:

1. Incidence and severity of mottled yolks in eggs laid by hens fed Nicarbazin was increased during storage.
2. The mottled areas on yolks produced by hens fed Nicarbazin were associated with a movement of water from the albumen to the yolk and this change accompanied a decrease in the fat content or an increase in the protein-fat ratio of the egg yolks.
3. The change in pH of mottled yolks from acid to alkaline was accompanied by a water movement from albumen to yolk.

The antioxidants, gallic acid and n-propylgallate, when fed at a level above that which occurred during normal feed consumption, increased the incidence of mottled yolks of eggs stored for two to three days at 55°F. (McNally and Brant, 1958). When tannic acid was fed to hens an increase

in number of mottled yolks resulted (McNally and Brant, 1958).

Dawson (1965) stated that certain worming compounds and ammonia gas have been known to cause mottled yolks. Peardon et al. (1965) studied the effects of piperazine, phenothiazine and dibutyltin dialaurate on egg production and egg quality. They found that eggs collected from hens given a double dosage of the triple combination of drugs consistently had a higher percentage of eggs with anomalies both as fresh and stored eggs than eggs from other groups of birds. Fry and Wilson (1965) reported that the worming compounds phenothiazine and piperazine caused no significant effect on yolk mottling when used at recommended levels. Both dibutyltin and a combination of the three wormers, however, showed significant and serious yolk mottling in eggs collected one week after treatment.

A study of the effects of piperazine citrate on egg yolks and egg production reported by Beane et al. (1960) indicated a significant increase in the occurrence of a darkening discoloration of portions of the egg yolk when that product was used.

Irregular areas of olive to brownish discoloration of the yolk were found by Beane et al. (1965) to occur more frequently in eggs from birds receiving piperazine compound treatments at twenty-eight day intervals than in eggs from controls. An increase in frequency was found to

occur with increased storage time under usual egg holding conditions. The highest incidence was found to occur during the warmest months of the year with a pronounced decrease to a very low level during the cool fall months.

Romanoff and Romanoff (1949) reported that mottled yolks were observed in stored eggs more frequently than in fresh eggs. Fry (1964) pointed out that yolk mottling, regardless of the type, increased with storage of the egg even for short periods, and that there appeared to be a time-temperature relationship.

Miller et al. (1957) showed that holding eggs at room temperature for three days resulted in 35 percent slightly mottled yolks and 25 percent moderately mottled yolks. Polin et al. (1956b) found an incidence of 12 percent mottled yolks in eggs stored at 50°F. Similar results were observed by Baker et al. (1957), McNally and Brant (1958), Mitchell and Stadelman (1958), and Blackshear et al. (1967a).

Season of the year was found by Blackshear et al. (1967a) to significantly influence both mean mottling scores and Haugh unit values. Mean mottling scores of fresh eggs collected in April were significantly higher than for eggs collected in either January or September which did not differ significantly from each other. These results are in agreement with those of Beane et al.

(1965).

Blackshear et al. (1967a) found no significant difference in egg mottling scores when comparing flocks which had no insecticide treatment with those which had been treated with sevin, malathion, or a combination of both compounds. However, mean mottling scores of birds in houses which were treated during this period. These results indicate that insecticides may increase egg mottling of both fresh and stored eggs.

Blackshear et al. (1967a) found that feed brand, use of water disinfectants and the washing or oiling of eggs had no significant effect on yolk mottling. The finding that oiling had no effect on mottling is at variance with the report of Heywang et al. (1962).

Chemical Composition of Mottled Yolks

Yolk mottling has been observed for many years, but the physical and chemical alterations of the yolk associated with the phenomenon have not received particular attention. The only data discovered were those which characterized a sample of mottled areas removed from boiled yolks, as having a higher protein-fat ratio than a sample of non-mottled yolks (Almquist, 1933).

Mottled yolks were reported to contain more water and less solids, lipids and nitrogen than non-mottled yolks by Polin (1957). He found yolk material intermingled with the inner thin layer of albumen in most eggs

with extremely mottled yolks. Polin (1957) agreed with the theory of Baker et al. (1956) that the water passing from the albumen into the yolk appeared to be involved in yolk mottling. Baker et al. (1956) reported that extremely mottled yolks from hens fed Nicarbazin had a more alkaline pH than control yolks.

Van Tienhoven et al. (1958) observed yolk weight differences between mottled and non-mottled egg yolks which were similar to those reported by Polin (1957). Mottled yolks contained a significantly higher water content than control yolks. No significant difference was observed between mottled and control eggs in behavior of the yolk contents to a standard membrane. The lack of difference in the ash content between the mottled and control yolks would substantiate the theory that yolk composition was not responsible for the added water uptake.

Polin (1960) in a review of "yolk-mottling," reported that the predominant change in mottled yolks was a movement of water from the albumen to the yolk. He stated that "mottling" occurred when yolk material passes into solution because the water, carrying with it buffered salts from the albumen shifted the pH of the yolk to the alkaline side. Polin (1960) thus described the mottled yolks as "watered-down" yolks.

Silvestrini et al. (1964) found that electrophoresis

analyses showed a direct relationship between mottled yolk score and the proportion of ovalbumin in the yolks. Furthermore, the lipovitellenin fraction of mottled yolks showed a change in mobility which did not occur in control egg yolks. This protein mobility difference was attributed to a chemical or physical change in the composition of the lipoprotein.

Definite changes in the composition of the lipoproteins of mottled yolks were discovered by Silvestrini et al. (1965). Although some of the chemical characterizations of the phospholipids and triglycerides of mottled and control yolks did not always agree with data found in the literature, gross differences in the lipid content of mottled and control yolks were indicative of structural changes.

Incidence, Severity and Scoring of Yolk Mottling

Literature on the incidence and severity of mottling among flocks of commercial hens is quite limited. Most research on the subject of mottling has evaluated discoloration after several months storage at low temperatures. However, it is important that producers, egg buyers, and retailers be aware that the action of discoloration or mottling is accentuated by higher temperatures and complaints may be forthcoming from consumers even though the eggs have been in market channels only a short period of time.

Blackshear et al. (1967b) found that in individual flocks the incidence of mottling in fresh eggs ranged from 11.1 to 91.7 percent while in stored eggs it ranged from 27.8 to 97.2 percent. Approximately 56 percent of all fresh eggs examined were mottled, and the mean mottling score was 1.60. Individual flock mean mottling scores ranged from 0.19 to 4.58.

Polin and Porter (1956) reported a high incidence (42 percent) of mottling during the first weeks of production and gradual decrease to a low of about 15 percent by the eleventh week of production.

Fry (1964) noted that in any flock, a limited amount of so-called "natural" yolk mottling occurs. He further noted that "natural" mottling occurs at a low level incidence and seldom was serious enough to cause consumer complaint.

Fry (1964) stated that the degree of mottling was commonly scored using a scale of zero to ten, with the zero referring to no mottling and ten referring to very severe mottling of the entire yolk and even the possibility of yolk seepage through the vitelline membrane. He theorized that the housewife would not likely notice mottling in the degree of one, two or three, but would note mottling with a score of four or higher.

Polin et al. (1957) developed a scoring system whereby

yolks were scored from zero to four, in units of one-half. Zero represented a yolk with no mottling, one-half a small amount of mottling, but only on close examination of the yolk was mottling detected. One to two was considered to be a moderately mottled yolk and two and one-half to four severely mottled.

Baker et al (1957) developed a scoring system based on a zero to ten scale. Zero indicated no detectable yolk damage, one to two designated a slight mottled appearance of the yolk, three to five indicated moderate mottling, easily detectable, but not objectionable to a customer, six to ten designated severe blemishing which would be objectionable to customers and have the appearance of a rotten yolk in the more severe cases.

Weiss (1957) and Heywang et al. (1955) each used a three point scoring system. Heywang and Lowe (1959) used a six point system based entirely on the color of the blemish: zero, no discoloration; one, very light brown; two, light brown; three, brown; four, dark brown; and five, black.

Silvestrini et al. (1964) developed a scoring system similar to that of Polin et al. (1957), except that the degree of mottling was scored from one to five. A score of one was considered to be very slight mottling. Yolks with a score of two were classified as slightly mottled, easily detectable but not too objectionable in appearance.

Yolks with moderate mottling were assessed a score of three, while severely mottled yolks were given a score of four. Very severely mottled yolks were given a score of five.

Blackshear et al. (1967a) decided that none of the systems in the literature fitted the need of their study and developed a system based on a ten point scale. Each point on the scale represented a different degree of mottling.

OBJECTIVES

This investigation was concerned with an evaluation of consumer acceptance of eggs having mottled yolks and the objectives were as follows:

1. To determine the reaction of consumers to egg yolks with varying degrees of mottling by use of consumer preference panels in Athens, Georgia and Detroit, Michigan.
2. To determine if various demographic factors such as age, education, income and location affect consumer preference for eggs having mottled yolks.
3. To determine at what level or degree of mottling the consumer rejects eggs having mottled yolks.
4. To ascertain the advisability of including these consumer preference data in the United States Department of Agriculture standards of quality for shell eggs.
5. To develop a subjective scoring system for evaluation of eggs having mottled yolks.

EXPERIMENTAL PROCEDURE

Two consumer preference panels were conducted to ascertain if "natural" mottling was objectionable and to determine at what level or degree of mottling consumers reject eggs having mottled yolks. The consumer preference panel technique was used to evaluate the desirability of certain attributes of the product. Thus, the consumer preference test was used to determine whether the consumer would accept the product.

Consumer Preference Panels

The method of collecting consumer preference data in this study was through the use of consumer panels in which the panel members made visual observations of the product. After examining the product, panel members ranked their preferences according to the scoring system that had been designed.

Two consumer preference panels using the appearance test were conducted. One preference panel was held in Detroit, Michigan and the other in Athens, Georgia.

In Detroit, the Michigan State University - Wayne State University Consumer Panel was used for a part of this study. According to Marquardt (1964) this panel was initiated in 1957 to evaluate consumer preferences among grades, varieties, sizes, color and processing techniques

for agricultural products. Consumers for the panel were selected at random from listings in the Detroit telephone directory.

Consumers ranked several different types of products at the panel meeting. Immediately prior to the panel session the groups of consumers were given instructions concerning the different series of items to be ranked. The products were displayed on tables in a large room, and ten to twenty consumers at a time proceeded independently to rank the samples within the room. When an individual consumer completed ranking of the products, the forms were checked to make certain that he had ranked all of the products within each series. A total of 135 consumers participated in the preference panel which was conducted on November 30, 1966.

For the Athens, Georgia panel, a random sample of consumers from the Athens area was drawn from the city directory. The prospective panel members were notified by mail of their selection. These individuals were then personally contacted to explain the proposed project, solicit their cooperation and participation, and obtain information on age, income and education. The preference panel was held in the Food Science Building on the University of Georgia campus on January 17, 1967 with 45 consumers participating.

These panels were designed to determine preferences of consumers with annual incomes ranging from under $2,000 to

over $10,000; of ages from under 30 to over 60 years, and with 0 to over 14 years of formal education. The panels were chosen without regard to ability to differentiate qualities of products.

Annual income of panel participants was divided into the following classifications: under $2,000; $2,000 - $3,999; $4,000 - $5,399; $5,400 - $6,999; $7,000 - $9,999 and $10,000 and over. Age classification ranges were: under 30, 31 - 45, 46 - 60, and over 60 years. Variation in education was analyzed according to the following classifications: 0 - 8 years, 9 - 11 years, 12 - 13 years, and over 14 years of formal education.

Test Procedure

The paired-comparison test was used in this study. In the paired-comparison test each panel member is presented with two coded samples and asked to compare them for some predesignated characteristic. The paired-comparison test also becomes a preference test when the panel members are asked whether they prefer one sample over the other (Baker, 1966). This test is most useful when the primary objective of the test is to measure the degree of difference rather than whether or not a difference does exist.

Operation of Panels

The consumers in both panels were not told the purpose of the paired-comparison test. They were only told to rank the pairs of eggs according to their preferences. The

panel members were not asked to explain the reasons for their preferences. The respondents could, however, make voluntary written comments regarding the eggs.

The samples were presented to the consumers in pairs for their evaluation. Eggs were displayed in white, glass dishes that were four inches in diameter. The samples were coded by typewriter symbols to prevent the possible influence of ranking association by use of letters or numbers. The five symbols used for the test were %, *, (), #, and &. The panelists were asked to rank each pair of eggs in order of their preference, using the figure one (1) for the sample most preferred and the figure (2) for the sample least preferred.

Egg Selection

Eggs shown the panel members in both panels were presorted by a committee of three people to assure than they were of approximately the same weight and had approximately the same albumen quality and depth of yellow color in the yolk. This was done in order to reduce the variability of these factors since they are known to influence consumer evaluations (Noles and Roush, 1962). Eggs shown the panel members having mottled yolks were produced by deliberate feeding of Nicarbazin to single comb White Leghorn hens in their third or fourth month of production.

The six degrees of mottling provided fifteen possible

pair or treatment combinations (Table 1). Each panel member evaluated five pairs of eggs. The pairings were randomly drawn without replacement until all possible combinations of pairs were used. This method provided data for one test with forty-five replications in the Detroit, Michigan panel and one test with fifteen replications in the Athens, Georgia panel.

Scoring System

After careful consideration and breaking several dozen eggs, it was decided that none of the scoring systems found in the literature were suitable for this study. Another scoring system was designed which more nearly complemented the procedures used in this study. The system was based on a six point scale, each point representing a different degree of mottling. The devised scoring system was as follows:

SCORE	YOLK MOTTLING DESCRIPTION
1	No visible mottling (Figure 1).
2	Slight mottling - usually one or two small oval blemishes or one blemish of .30 cm. in diameter or less (Figure 2).
3	Moderate mottling - often appearing as swirls or undulate shape covering 5 - 15 percent of the exposed yolk surface (Figure 3).
4	Severe mottling - covering 15 to 33 percent of the exposed yolk surface (Figure 4).

5	Very severe mottling - covering 33 to 60 percent of the exposed yolk surface (Figure 5).
6	Extreme mottling - covering 60 to 100 percent of the exposed yolk surface (Figure 6).

Statistical Analysis

The method of paired comparisons employing unequal repetition of pairs (Dykstra, 1960) was used to determine the overall preference of samples in the consumer preference panels. This program, coded in Fortran IV for the IBM 7094 computer, is based on the Bradley and Terry (1952) method of paired comparisons, and a computer program written by Dykstra (1960).

The function of this program was to accept raw data collected in the study and compute the results for each pair of eggs. The rating percentages for each sample were then calculated in order to test the null hypothesis that all percentages are equal and that consumers have no preferences regarding degree of mottling in egg yolks. The null hypothesis was subjected to the Chi Square method of analysis. After the sample preferences and standard deviations were computed, the Student-t distribution test was used to determine significant difference between samples. Significant samples were treated by Duncan's multiple range test (Duncan, 1955).

Data obtained from the two consumer preference panels were combined and analyzed to determine the effect of various

demographic factors on preference for mottling in egg yolks. These data were analyzed by analysis of variance test and subjected to Duncan's multiple range test (Duncan, 1955).

Table 1. Pair Combinations Evaluated by Consumers

Sample 1 (no visible mottling) versus Sample 2 (slight mottling)
Sample 1 (no visible mottling) versus Sample 3 (moderate mottling)
Sample 1 (no visible mottling) versus Sample 4 (severe mottling)
Sample 1 (no visible mottling) versus Sample 5 (very severe mottling)
Sample 1 (no visible mottling) versus Sample 6 (extreme mottling)
Sample 2 (slight mottling) versus Sample 3 (moderate mottling)
Sample 2 (slight mottling) versus Sample 4 (severe mottling)
Sample 2 (slight mottling) versus Sample 5 (very severe mottling)
Sample 2 (slight mottling) versus Sample 6 (extreme mottling)
Sample 3 (moderate mottling) versus Sample 4 (severe mottling)
Sample 3 (moderate mottling) versus Sample 5 (very severe mottling)
Sample 3 (moderate mottling) versus Sample 6 (extreme mottling)
Sample 4 (severe mottling) versus Sample 5 (very severe mottling)
Sample 4 (severe mottling) versus Sample 6 (extreme mottling)
Sample 5 (very severe mottling) versus Sample 6 (extreme mottling)

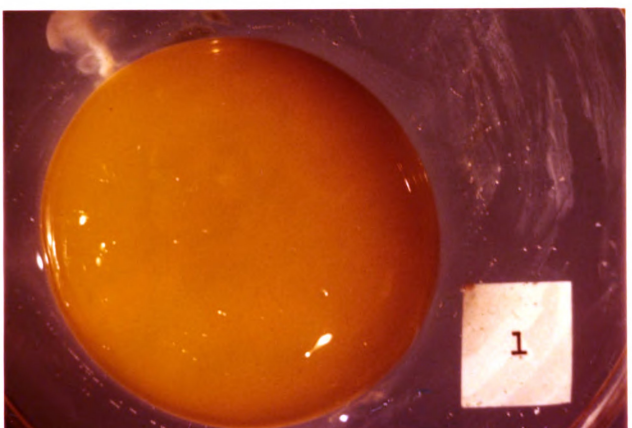

Figure 1. A Photograph of An Egg With a Score of One (1) Showing No Visible Yolk Mottling.

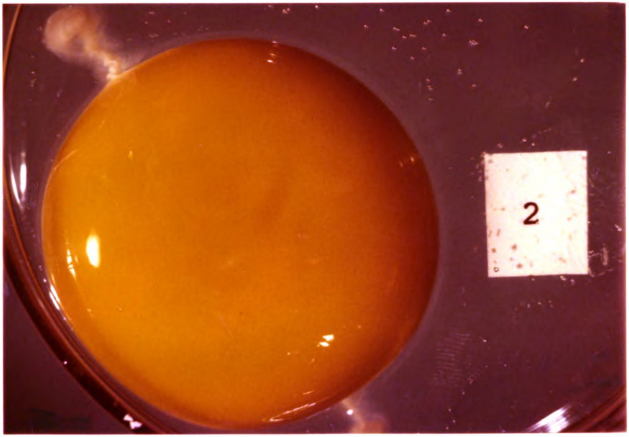

Figure 2. A Photograph of an Egg With a Score of Two (2) Showing Slight Yolk Mottling.

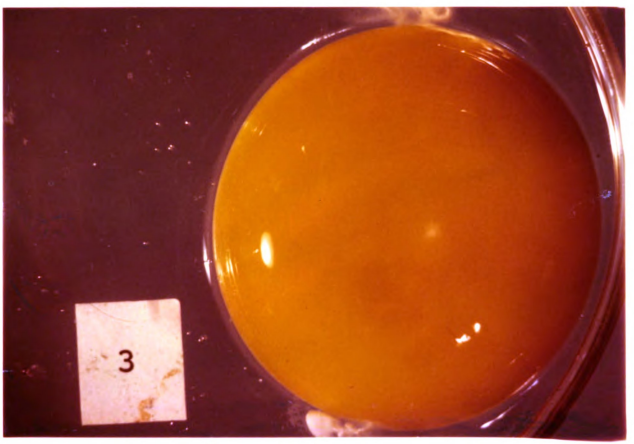

Figure 3. A Photograph of an Egg With A Score of Three (3) Showing Moderate Yolk Mottling.

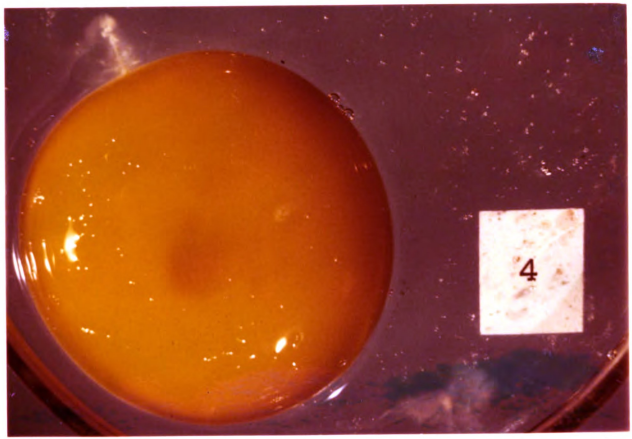

Figure 4. A Photograph of an Egg With a Score of Four (4) Showing Severe Yolk Mottling.

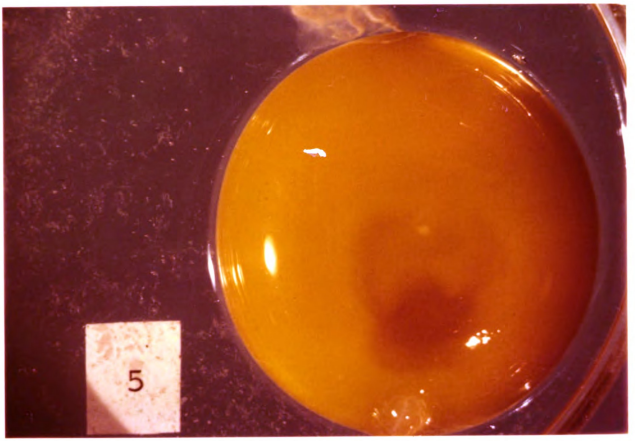

Figure 5. A Photograph of an Egg With a Score of Five (5) Showing Very Severe Yolk Mottling.

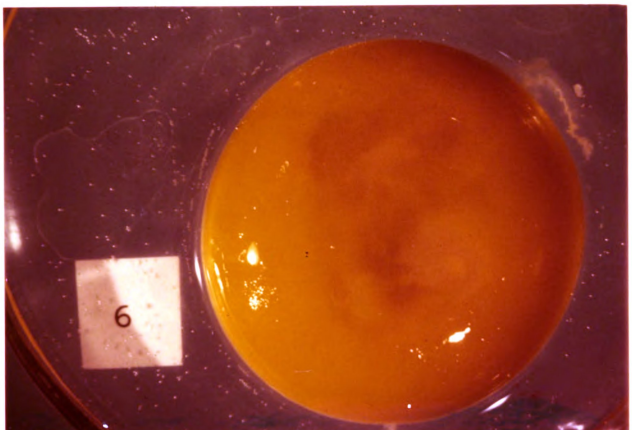

Figure 6. A Photograph of an Egg With a Score of Six (6) Showing Extreme Yolk Mottling.

RESULTS

Results obtained from the two consumer preference panels on egg yolk mottling are shown below as analyzed by the Dykstra analysis method and subjected to Duncan's multiple range test.

Athens Location

The number of Athens consumer panelists that preferred one sample over another are shown in Table 2. A total of 45 consumers supplied information for the test. The data reveal that Sample 2, slight yolk mottling, (Figure 2) was actually preferred by consumers 8 more times than was Sample 1, no visible yolk mottling, (Figure 1). Each sample was viewed 75 times. Sample 2, slight mottling, was preferred 58 times and rejected only 17 times by the consumers. Sample 3, moderate yolk mottling, (Figure 3) received the second highest number of wins (number of times preferred) with Sample 1, no visible mottling, ranking third in the total number of times preferred by consumers. Sample 3 was preferred 55 times whereas Sample 1 was preferred only 50 times. Sample 6, extreme yolk mottling, (Figure 6) was preferred the fewest number of times with this sample being rejected by every panel member in the test.

Consumer preference for paired degrees of yolk mottling are shown in Table 3. The data show the number of times

Table 2. Consumer Preference for Eggs With Each Degree of Yolk Mottling. (Athens Location)

Sample	Number of Consumers Preferring Sample	Number of Consumers Rejecting Sample	Number of Times Sample was Seen
1 (no mottling)	50.0	25.0	75.0
2 (slight mottling)	58.0	17.0	75.0
3 (moderate mottling)	55.0	20.0	75.0
4 (severe mottling)	39.0	36.0	75.0
5 (very severe mottling)	23.0	52.0	75.0
6 (extreme mottling)	0.0	75.0	75.0
TOTAL	225.0	225.0	450.0

Table 3. Consumer Preference for Paired Degrees of Yolk Mottling (Athens Location).

Paired Samples	Number of Times Preferred
Sample 1 versus Sample 2	3
Sample 1 versus Sample 3	6
Sample 1 versus Sample 4	12
Sample 1 versus Sample 5	14
Sample 1 versus Sample 6	15
Sample 2 versus Sample 1	12
Sample 2 versus Sample 3	7
Sample 2 versus Sample 4	11
Sample 2 versus Sample 5	13
Sample 2 versus Sample 6	15
Sample 3 versus Sample 1	9
Sample 3 versus Sample 2	8
Sample 3 versus Sample 4	9
Sample 3 versus Sample 5	14
Sample 3 versus Sample 6	15
Sample 4 versus Sample 1	3
Sample 4 versus Sample 2	4
Sample 4 versus Sample 3	6
Sample 4 versus Sample 5	11
Sample 4 versus Sample 6	15
Sample 5 versus Sample 1	1
Sample 5 versus Sample 2	2
Sample 5 versus Sample 3	1
Sample 5 versus Sample 4	4
Sample 5 versus Sample 6	15
Sample 6 versus Sample 1	0
Sample 6 versus Sample 2	0
Sample 6 versus Sample 3	0
Sample 6 versus Sample 4	0
Sample 6 versus Sample 5	0

each sample (degree of mottling) was preferred when paired with another sample of different degree of yolk mottling. The consumer preferences are shown for each pair of the fifteen possible pair combinations.

In the Athens panel, Sample 2, slight yolk mottling, (Figure 2) when paired with Sample 1, no visible yolk mottling, (Figure 1) was preferred by consumers twelve out of a possible fifteen time. Sample 1 was selected as first choice in only three instances. A pairing of Sample 3, moderate yolk mottling, (Figure 3) and Sample 1, no visible yolk mottling, (Figure 1) revealed that Sample 3 was preferred nine times and Sample 1 preferred only six times. Sample 3, moderate yolk mottling, (Figure 3) was also preferred by panelists over Sample 2, slight yolk mottling (Figure 2). Sample 3 was preferred eight times and Sample 2 preferred seven times. In all other possible pair combinations the sample with the lowest degree of mottling was selected over the sample with the highest degree of yolk mottling. As can be seen from the data in Table 3, Sample 6, extreme yolk mottling, (Figure 6) was actually rejected by these consumers in every pair combination.

Estimates of the probability of preferences for each sample in the Athens consumer preference panel are shown in Table 4. The hypothesis according to Dykstra (1960) states that there is no consumer preference among the six

Table 4. Estimates of Probability of Consumer Preference (Athens Location).

Sample	Expected Probability	Actual Probability
1	0.090909	0.000074
2	0.055375	0.000044
3	0.067797	0.000054
4	0.155844	0.000149
5	0.311377	0.000503
6	1.000000	0.999176

These probability values were significant at the one percent level of significance ($P \leq 0.01$).

treatments (expected probability and actual probability). Chi Square analysis of the data with T - 1 = 5 degrees of freedom gave a value of 152.87 for the Athens data. This value was significant at the one percent level of probability which rejects the hypothesis of no consumer preference of samples.

The six treatments used in the Athens panel are shown in Table 5 by paired preferences using the Students Statistical Analysis. Results of the test indicate no significant difference in preference with a pairing of Sample 1, no visible mottling, (Figure 1) and Sample 2, slight mottling, (Figure 2). No significant difference in preference was indicated between Sample 1, no visible mottling, (Figure 1) and Sample 3, moderate mottling, (Figure 3) and between Sample 2, slight mottling, (Figure 2) and Sample 3, moderate mottling, (Figure 3). In all other pair combinations the sample with the lesser degree of mottling was preferred. These preferences were significant at the one percent level of probability.

The significant samples were then treated by Duncan's multiple range test and the results are shown in Table 6. Samples 1 and 2 (no visible mottling and slight mottling) were similar to each other. However, they were not significantly different from Samples 2 and 3 (slight mottling and moderate mottling) which were also similar to each other.

Table 5. Analysis of Preference for Paired Samples (Athens Location).

Samples	Student Test	
Sample 1 versus Sample 2	- 6.3329	N.S.
Sample 1 versus Sample 3	- 3.9507	N.S.
Sample 1 versus Sample 4	8.3630	* *
Sample 1 versus Sample 5	18.5841	* *
Sample 1 versus Sample 6	24.9963	* *
Sample 2 versus Sample 1	6.3329	N.S.
Sample 2 versus Sample 3	2.4815	N.S.
Sample 2 versus Sample 4	13.5479	* *
Sample 2 versus Sample 5	20.9685	* *
Sample 2 versus Sample 6	24.9978	* *
Sample 3 versus Sample 1	3.9507	N.S.
Sample 3 versus Sample 2	- 2.4815	N.S.
Sample 3 versus Sample 4	11.6955	* *
Sample 3 versus Sample 5	20.1659	* *
Sample 3 versus Sample 6	24.9973	* *
Sample 4 versus Sample 1	- 8.3630	* *
Sample 4 versus Sample 2	-13.5479	* *
Sample 4 versus Sample 3	-11.6995	* *
Sample 4 versus Sample 5	13.6040	* *
Sample 4 versus Sample 6	24.9926	* *
Sample 5 versus Sample 1	-18.5841	* *
Sample 5 versus Sample 2	-20.9685	* *
Sample 5 versus Sample 3	-20.1659	* *
Sample 5 versus Sample 4	-13.6040	* *
Sample 5 versus Sample 6	24.9748	* *
Sample 6 versus Sample 1	-24.9963	* *
Sample 6 versus Sample 2	-24.9978	* *
Sample 6 versus Sample 3	-24.9973	* *
Sample 6 versus Sample 4	-24.9926	* *
Sample 6 versus Sample 5	-24.9748	

Note: N.S. - Not Significant at the one percent level of significance ($P \leq 0.01$)
* * - Significant at the one percent level of significance ($P \leq 0.01$)

Table 6. Consumer Preference of Egg Mottling Samples. Evaluated by Multiple Range Test (Athens Location).

Sample:	1	2	3	4	5	6

Note: Any two figures not underscored by the same line are significantly different at the one percent level of significance ($P \leq 0.01$).

Any two figures underscored by the same line are not significantly different at the one percent level of significance ($P \leq 0.01$).

The multiple range test analysis revealed that there was no significant difference between Samples 1, 2, and 3 (no visible yolk mottling, slight mottling and moderate mottling), respectively.

Detroit Location

The number of Detroit consumer panelists that preferred one sample over another, are shown in Table 7. A total of 135 consumers supplied information for the test. The data in this table reveal that Sample 2, slight yolk mottling, (Figure 2) was actually preferred 12 more times than was Sample 1, no visible yolk mottling, (Figure 1). Out of a possible 225 observations, Sample 2 was selected as first choice 154 times. The sample was rejected only 71 times. Sample 1, no visible yolk mottling, (Figure 1) ranked second in preference and Sample 3, moderate yolk mottling, (Figure 3) ranked third in the number of times preferred by consumers. Sample 1 was selected as first choice 142 times and Sample 3 was selected 120 times. Sample 6, extreme yolk mottling, (Figure 6) was preferred the fewest number of times.

The consumer preference for paired degrees of mottling are shown in Table 8. The number of times each sample or degree of mottling was preferred when paired with another sample of a varying degree of yolk mottling is shown. Consumer preferences are given for each pairing

Table 7. Consumer Preference for Each Degree of Yolk Mottling (Detroit Location).

Sample	Number of Consumers Preferring Sample	Number of Consumers Rejecting Sample	Number of Times Sample was seen
1 (no mottling)	142.0	83.0	225.0
2 (slight mottling)	154.0	71.0	225.0
3 (moderate mottling)	120.0	105.0	225.0
4 (severe mottling)	112.0	113.0	225.0
5 (very severe mottling)	85.0	140.0	225.0
6 (extreme mottling)	62.0	163.0	225.0
TOTAL	675.0	675.0	1,350.0

Table 8. Consumer Preference for Paired Degrees of Yolk Mottling (Detroit Location).

Paired Samples	Number of Times Preferred
Sample 1 versus Sample 2	17
Sample 1 versus Sample 3	27
Sample 1 versus Sample 4	33
Sample 1 versus Sample 5	34
Sample 1 versus Sample 6	40
Sample 2 versus Sample 1	28
Sample 2 versus Sample 3	36
Sample 2 versus Sample 4	36
Sample 2 versus Sample 5	35
Sample 2 versus Sample 6	30
Sample 3 versus Sample 1	18
Sample 3 versus Sample 2	9
Sample 3 versus Sample 4	27
Sample 3 versus Sample 5	24
Sample 3 versus Sample 6	42
Sample 4 versus Sample 1	12
Sample 4 versus Sample 2	9
Sample 4 versus Sample 3	18
Sample 4 versus Sample 5	32
Sample 4 versus Sample 6	21
Sample 5 versus Sample 1	11
Sample 5 versus Sample 2	10
Sample 5 versus Sample 3	21
Sample 5 versus Sample 4	13
Sample 5 versus Sample 6	30
Sample 6 versus Sample 1	5
Sample 6 versus Sample 2	15
Sample 6 versus Sample 3	3
Sample 6 versus Sample 4	24
Sample 6 versus Sample 5	15

of the fifteen possible pair combinations.

In the pairwise preference (Table 8) Sample 2, slight yolk mottling, (Figure 2) was preferred to Sample 1, no visible yolk mottling, (Figure 1). Sample 2 was selected 28 times with Sample 1 being preferred only 17 times. Sample 1, no visible mottling, (Figure 1), however, was selected by consumers over Sample 3, moderate mottling, (Figure 3). In all other pair combinations the sample with the lower degree of mottling was preferred by consumers over the sample with the higher degree of yolk mottling. The sample with the higher degree of mottling was selected by some consumers in every pair combination.

Estimates of the probability of preference for each sample by the Detroit consumer preference panel are shown in Table 9. Again the hypothesis states that there is no consumer preference among the six treatments (degree of mottling). Data analyzed by the Chi Square method of analysis with T - 1 = 5 degrees of freedom gave a value of 92.468. This value was significant at the one percent level of probability and rejects the hypothesis of no preference of samples.

The six treatments of degrees of yolk mottling evaluated by the Detriot panel members are shown in Table 10 by pairwise preferences using the Students Statistical Analysis method. No significant difference in preference

Table 9. Estimates of Probability of Consumer Preference (Detroit Location).

Sample	Expected Probability	Actual Probability
1	0.104666	0.090607
2	0.084423	0.074017
3	0.148936	0.129061
4	0.167905	0.146441
5	0.247788	0.225572
6	0.344609	0.334302

These probability values were significant at the one percent level of significance ($P \leq 0.01$).

Table 10. Analysis of Preference for Paired Samples (Detroit Location).

Samples	Student Test	
Sample 1 versus Sample 2	- 2.5195	N.S.
Sample 1 versus Sample 3	4.3763	*
Sample 1 versus Sample 4	5.8884	* *
Sample 1 versus Sample 5	10.6715	* *
Sample 1 versus Sample 6	14.3380	* *
Sample 2 versus Sample 1	2.5195	N.S.
Sample 2 versus Sample 3	6.7763	* *
Sample 2 versus Sample 4	8.2129	* *
Sample 2 versus Sample 5	12.6470	* *
Sample 2 versus Sample 6	15.9364	* *
Sample 3 versus Sample 1	- 4.3763	*
Sample 3 versus Sample 2	- 6.7763	* *
Sample 3 versus Sample 4	7.5771	* *
Sample 3 versus Sample 5	6.8036	* *
Sample 3 versus Sample 6	11.0734	* *
Sample 4 versus Sample 1	- 5.8884	* *
Sample 4 versus Sample 2	- 8.2129	* *
Sample 4 versus Sample 3	- 7.5771	* *
Sample 4 versus Sample 5	5.3178	* *
Sample 4 versus Sample 6	9.7693	* *
Sample 5 versus Sample 1	-10.6715	* *
Sample 5 versus Sample 2	-12.6470	* *
Sample 5 versus Sample 3	- 6.8036	* *
Sample 5 versus Sample 4	- 5.3178	* *
Sample 5 versus Sample 6	4.8551	* *
Sample 6 versus Sample 1	-14.3380	* *
Sample 6 versus Sample 2	-15.9364	* *
Sample 6 versus Sample 3	-11.0734	* *
Sample 6 versus Sample 4	- 9.7693	* *
Sample 6 versus Sample 5	- 4.8551	* *

Note: N.S. - Not Significant at one percent level of significance ($P \leq 0.01$).
* - Significant at five percent level of significance ($P \leq 0.05$).
* * - Significant at one percent level of significance ($P \leq 0.01$).

was indicated with a pairing of Sample 1, no visible mottling, and Sample 2, slight mottling. In pairing of Sample 1, no visible mottling, and Sample 3, moderate mottling, Sample 1 was preferred.

The statistical significant samples in this test were also treated by Duncan's multiple range test method as shown in Table 11. Samples 1 and 2, no visible mottling and slight mottling, were similar to each other. They were, however, significantly different from Samples 1 and 3, no visible mottling and moderate mottling, which were also similar to each other. No significant difference was found between Samples 1 and 2, however, there was significant differences between Samples 1 and 3. The standard deviation for the Sample 1 versus Sample 3 pairing at the five percent level of probability was 4.3033 and the pairwise preference was 4.3763. This difference was not significant at the one percent level of probability.

Combined Locations

Data obtained from the two consumer preference panels were combined and analyzed to determine the effect of various demographic factors on preference for mottled yolks. The factors studied were age, education, income, location, and test. These data were analyzed by analysis of variance test and subjected to Duncan's multiple range test.

The effect of various demographic factors by percent

Table 11. Consumer Preference of Egg Mottling Samples. Evaluated by Multiple Range Test (Detroit Location).

Sample:	1	2	3	4	5	6

Note: Any two figures not underscored by the same line are significantly different at the one percent level of significance ($P \leq 0.01$).

Any two figures underscored by the same line are not significantly different at the one percent level of significance ($P \leq 0.01$).

of consumers preferring the lesser degree of mottling in each of the treatment combinations is shown in Table 12. Only 27.8 percent of the consumers preferred Sample 1, no visible mottling, (Figure 1) over Sample 2, slight mottling, (Figure 2). In the combined data a total of 72.2 percent of the panelists actually preferred eggs with slight yolk mottling. Moderate yolk mottling was preferred by 52.6 percent of the panel members over eggs with no visible mottling. With the exception of treatment combinations Sample 1 versus Sample 2 and Sample 1 versus Sample 3, eggs with the lesser degree of mottling were selected as first choice in each treatment combination (Table 12).

Effect of Age on Consumer Preference

In this study on effect of age of consumer preference for eggs having mottled yolks, it was found that consumer preference was practically the same regardless of age of consumers (Table 13).

Upon interpreting the analysis of variance for difference in consumer preference, as measured by the percent consumers selecting eggs with the lesser degree of mottling, it was found that age effect was not significant at the one percent probability level (Table 13). This was due to the small amount of variation found to exist in consumer preference for each of the treatment combinations. Although there was a tendency for older consumers to prefer

Table 12. Effect of Location on Consumer Preference for Eggs Having Mottled Yolks.

Treatment Combination	Percent of Consumers Preferring Lesser Degree of Mottling		
	Athens	Detroit	Combined
Sample 1 versus Sample 2	19.2	36.5	27.8
Sample 1 versus Sample 3	40.0	54.9	47.4
Sample 1 versus Sample 4	79.1	57.8	63.5
Sample 1 versus Sample 5	93.0	79.9	86.5
Sample 1 versus Sample 6	100.0	92.2	96.2
Sample 2 versus Sample 3	45.6	81.5	63.5
Sample 2 versus Sample 4	73.1	81.0	77.1
Sample 2 versus Sample 5	85.1	81.2	83.1
Sample 2 versus Sample 6	99.7	88.6	94.1
Sample 3 versus Sample 4	60.2	63.9	62.0
Sample 3 versus Sample 5	93.1	58.2	75.7
Sample 3 versus Sample 6	99.7	96.6	98.2
Sample 4 versus Sample 5	73.0	69.7	71.4
Sample 4 versus Sample 6	99.1	59.2	74.2
Sample 5 versus Sample 6	99.3	70.6	85.0

Table 13. Analysis of Variance: Effect of Age, Education, Income, Test, and Location on Consumer Preference for Eggs Having Mottled Yolks.

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Values
Total	886	184.2		
Treatment	39	29.4	.75	4.18
Test	14	16.3	1.16	6.36**
Age	3	.8	.28	1.53
Education	3	.3	.09	0.48
Income	4	.3	.08	0.43
Location	1	.5	.50	2.75
Location vs Test	14	10.1	.76	4.17**
Error	847	154.7	.18	

** - Significant at the one percent level of probability ($P \leq 0.01$).

eggs with less mottling, differences were not statistically significant at the one percent level of significance. (Table 14).

Effect of Education on Consumer Preference

The effect of education on consumer preference was also found to be practically the same regardless of the educational level of consumers (Table 13). A total of 71.9 percent of consumers with 0 - 8 years of formal education selected eggs with the lesser degree of mottling compared with 72.0 percent of consumers with 9 - 11 years of education. Seventy-five percent of consumers with 12 - 13 years of education selected samples with less mottling compared with 76.0 percent with 14 or more years of formal education. While there was a tendency for consumers with higher educational levels to select eggs with less mottling, these differences were not statistically significant at the one percent level of significance (Table 15). No significant difference was found between any of the various educational levels.

Effect of Income on Consumer Preference

The analysis of variance on the effect of income on consumer preference for eggs having mottled yolks revealed that no significant difference existed at the one percent level of significance (Table 13). The tendency was for consumers with higher income levels to select eggs with

Table 14. Percent of Consumers Preferring Lesser Degree of Mottling by Age Group. Evaluated by Multiple Range Test.

Age Group:	Under 30	31-45	46-60	Over 60
Means (Percent)	69.1[a]	73.6[a]	74.2[a]	76.8[a]

[a]Those means with the same superscript are not significantly different at the one percent level of significance ($P \leq 0.01$).

Table 15. Percent of Consumers Preferring Lesser Degree of Mottling by Educational Levels. Evaluated by Multiple Range Test.

Educational Levels	0-8 years	9-11 years	12-13 years	14 or more years
Means (percent)	71.9[a]	72.0[a]	75.1[a]	76.0[a]

[a]Those means with the same superscript are not significantly different at the one percent level of significance ($P \leq 0.01$).

less mottling, however, no significant difference was found at the one percent level between any of the various income levels on consumer preference (Table 16).

Effect of Location on Consumer Preference

The data were analyzed to determine if differences existed in consumer preference at each of the two test locations, Athens and Detroit (Table 13). A total of 77.3 percent of the Athens' consumers preferred eggs with less mottling while 74.6 percent of the Detroit consumers selected eggs with less mottling. Again, these differences were not statistically significant at the one percent level of significance (Table 17).

Effect of Test on Consumer Preference

Each of the fifteen possible combinations were analyzed to determine the effect of test treatment on consumer preference.

Upon interpreting the analysis of variance for difference in consumer preference, as measured by percent of consumers preferring the sample with less mottling, it was found that test effect was significant at the one percent probability level (Table 13). This was due to the variation found to exist in consumer preference for eggs with low levels of mottling.

Duncan's multiple range test analysis revealed that there was no significant difference at the one percent level

Table 16. Percent of Consumers Preferring Lesser Degree of Mottling by Income Levels. Evaluated by Multiple Range Test.

Income Levels:					
Under $2,000	$2,000-$3,999	$4,000-$5,399	$5,400-$6,999	$7,000-$9,999	Over $10,000
Means (Percent):					
71.2[a]	71.4[a]	72.4[a]	73.6[a]	76.0[a]	76.5[a]

[a]Those means with the same superscript are not significantly different at the one percent level of significance ($P \leq 0.01$).

Table 17. Percent of Consumers Preferring Lesser Degree of Mottling at Each Location. Evaluated by Multiple Range Test.

Location:	Athens	Detroit
Means (Percent)	77.3[a]	74.6[a]

[a]Those means with the same superscript are not significantly different at the one percent level of significance ($P \leq 0.01$).

between Sample 1, no visible mottling, (Figure 1) and Sample 2, slight yolk mottling, (Figure 2) at either test location. Sample 1, no visible mottling, (Figure 1) and Sample 3, moderate mottling, (Figure 3) were not significantly different in the Athens test. The difference in the Detroit test was significant at the five percent level, but not at the one percent level. Sample 2 did not differ significantly from Sample 3 in the Athens test, but these were statistically significant at the one percent level in the Detroit test. No significant differences existed between the other paired treatments at either test location.

Table 18. Percent of Consumers Preferring Lesser Degree of Mottling by Test. Evaluated by Multiple Range Test.

Test Treatments	Means (Percent)
Sample 1 versus Sample 2	27.8[a]
Sample 1 versus Sample 3	47.4[b]
Sample 1 versus Sample 4	63.5[d]
Sample 1 versus Sample 5	86.5[d]
Sample 1 versus Sample 6	96.2[d]
Sample 2 versus Sample 3	63.6[c]
Sample 2 versus Sample 4	77.1[c]
Sample 2 versus Sample 5	93.1[d]
Sample 2 versus Sample 6	84.1[d]
Sample 3 versus Sample 4	62.0[d]
Sample 3 versus Sample 5	75.7[d]
Sample 3 versus Sample 6	98.2[d]
Sample 4 versus Sample 5	71.4[d]
Sample 4 versus Sample 6	74.2[d]
Sample 5 versus Sample 6	84.9[d]

[a]Those means with the same subscript are not significantly different at the one percent level of significance ($P \leq 0.01$).

[b]Those means with this subscript were significantly different at the five percent level of significance ($P \leq 0.05$) in Detroit but not in Athens.

[c]Those means with this subscript were significantly different at the one percent level of significance ($P \leq 0.01$) in Detroit but not in Athens.

[d]Those means with this subscript are significantly different at the one percent level of significance ($P \leq 0.01$).

DISCUSSION

One objective of this study was to establish a subjective system for scoring mottling in egg yolks. A review of the literature revealed that a number of scoring systems had been devised for assessing the degree of yolk mottling.

Polin, Ott and Siegmund (1957) developed a scoring system whereby varying degrees of yolk mottling were scored from 0.0 to 4.0, in units of 0.5. Zero represented a yolk with no mottling whereas 4.0 represented a severely mottled yolk. Baker et al. (1957), Fry (1964) and Blackshear et al. (1967) developed scoring systems based on a zero to 10 scale with zero again indicating no detectable yolk damage and a score of 10 indicating severe blemishing. Weiss (1957) and Heywang et al. (1955) each devised a three point scoring system for assessing the degree of yolk mottling. Heywang and Lowe (1959) used a six point system based entirely on the color of the blemish.

For the purpose of this study a six point system was devised which would more nearly fulfill the objectives and procedures used in this study. The scoring system is based on a six point scale with each point representing a varying degree of yolk mottling.

This scoring system was found to be very effective in assessing the varying degrees of yolk mottling. It was also effectively used with the application of the Dykstra statistical test analysis. The scoring system allowed for a large number of replications as there were six degrees of yolk mottling which gave fifteen possible combinations of pairs. A group of three panel members examined five pairs of eggs drawn randomly without replacement which exhausted the fifteen possible combinations. This procedure allowed fifteen replications of the test in the Athens panel and forty-five replications in the Detroit panel.

After establishment of an effective scoring system, two consumer preference panels were established and conducted to determine the reaction of consumers to eggs having varying degrees of yolk mottling. The hypothesis being that there was no consumer preference among the six treatments. Data analyzed by the Chi Square method of analysis, however, indicated significance at the one percent level of probability which rejects the hypothesis of no preference of samples. These data were analyzed by the Dykstra analysis method, a program written for the computer to analyze consumer panel results employing unequal repetition of pairs used to determine overall consumer preference.

Blackshear et al. (1967a) found that a large amount of so-called "natural mottling" occurs. Results of this study indicated that 56.07 percent of all fresh eggs sampled randomly at farms were mottled to some degree. This "natural mottling" was not believed to be serious enough to cause consumer complaints and marketing problems, however, a review of literature revealed that very little information was available on consumer reactions to eggs having mottled yolks.

Another objective of this study was to determine consumer reactions to eggs with varying degrees of yolk mottling. Data collected from these consumer panels revealed that consumers actually preferred eggs with slight yolk mottling to eggs with no visible yolk mottling. This was true in both consumer preference panels. In both tests, Sample 2, slight yolk mottling, usually appearing as one or two small oval blemishes or one blemish of a .30 cm in diameter or less, was actually preferred by consumers a larger number of times than was Sample 1, no visible yolk mottling. Chi Square and multiple range analysis of these data revealed that while slight yolk mottling was actually preferred by consumers, the difference was not significant at the one percent level of probability.

In the Athens test, a pairing of Sample 1, no visible yolk mottling, with Sample 3, moderate yolk mottling,

revealed that Sample 3 was preferred to Sample 1. Sample 3 was also preferred over Sample 2, slight yolk mottling, in this test. Chi Square analysis again revealed that while an egg with moderate yolk mottling was actually preferred over an egg with no visible mottling or slight mottling, the degree of preference was not significant at the one percent probability level.

The data obtained from the Detroit test were similar to those obtained from the Athens test. Sample 2, slight yolk mottling, again was preferred a larger number of times than Sample 1 with no visible yolk mottling. These results, however, were not statistically significant.

Sample 1, no visible mottling, was selected by consumers over Sample 3, moderate mottling, in the Detroit test. This is in contrast to the results obtained in the Athens test. Chi Square analysis revealed the standard deviation at the five percent level of probability to be 4.3033 and the pair-wise preference for Sample 1 versus Sample 3 was 4.3763. The selection of Sample 1 over Sample 3 was statistically significant at the five percent probability level, however, it was extremely close as shown by comparison of the standard deviation and pair-wise preference. These data were not significant at the one percent probability level. Application of Duncan's multiple range test revealed that Samples 1 and 2 were

similar. However, they were significantly different from Samples 1 and 3 which were also similar to each other.

No significant difference was found between Samples 1 and 2, however, there was a significant difference at the five percent level between Samples 1 and 3.

The data obtained from the two consumer preference panels indicate that "natural" mottling found in eggs was not objectionable to consumers. Mean mottling scores on eggs with "natural" mottling were found by Blackshear et al. (1967b) to be 1.60 for fresh eggs and 2.52 for stored eggs. These mottling scores were comparable to a score of two (2) in the scoring system used in this study. The consumer preference data indicate that eggs with a score of two (2) and three (3) having slight to moderate yolk mottling were not objectionable to consumers.

In all other possible combination of pairs the sample with the lesser degree of mottling was preferred by consumers over the sample with the higher degree of yolk mottling. Samples 4, 5 and 6 definitely were objectionable to consumers and the preference was significant at the one percent probability level in both consumer panels.

In the Athens panel Sample 6, extreme mottling, was objectionable to every panel member. However, in every pair combination some of the Detroit panelist selected the egg with the higher degree of yolk mottling. This variation in results could have been caused by slight

variations in the amount or intensity of mottling in the eggs selected for panel use or possibly because the Detroit consumers were not as aware of the mottling condition. It is possible that egg yolk mottling is more prevalent in the South than in other areas of the country. This factor is quite possible due to feeding of poultry rations containing cottonseed meal and greater use of worming compounds such as piperazine and dibutyltin dilurate in the southern states.

The selection of the higher degree of mottling in every pair combination by the Detroit panel and in every combination except where Sample 6 was used in the Athens panel indicates that some consumers do not reject eggs with mottled yolks regardless of the degree and intensity of mottling or that their selection was based on factors other than mottling.

Data obtained from these two consumer preference panels show that "natural mottling" found in eggs is not objectionable and that consumers do not notice mottling at low level incidence. These results are in agreement with those obtained by Baker et al. (1957) and Fry (1964) who theorized that consumers would not likely notice mottling in the degree of one, two or three, but would note mottling with a score of four or higher. Moderate mottling, often appearing as swirls or undulate shape,

covering 5 to 15 percent of the exposed yolk surface, appears to be the breaking point for consumer acceptance of eggs having mottled yolks. Mottling above this level was found at the one percent probability level to be objectionable to consumers with mottling of this degree and less not being objectionable.

Various demographic factors such as age, education, income, and location were evaluated with respect to consumer preference. Analysis of variance revealed that no significant difference in consumer preference for eggs having mottled yolks occurred when age, education, income, and location were considered. It was found that consumer preference was practically the same regardless of these factors. Although there was a tendency for older consumers, and consumers with higher educational and income levels to prefer eggs with less yolk mottling, these differences were not statistically significant. Duncan's multiple range test analysis revealed no significant difference at the one percent level between these factors on consumer preference for mottled yolks.

When each of the fifteen test combinations were analyzed to determine the effect of test treatments on consumer preference a significant difference was found. Upon interpreting the analysis of variance, it was found that test effect was significant at the one percent probability level. This situation was probably due to

the variation found to exist in consumer preference for eggs with low levels of mottling. In both panel locations, panel members preferred eggs with slight yolk mottling, over eggs with no visible mottling. Moderate yolk mottling was selected over no visible mottling by the majority of panelists in the Athens location and by 45.1 percent of the panel members at the Detroit location. While these results were not statistically significant, they indicate that many consumers do not reject eggs with low levels of mottling or that their selection was based on factors more important to them than yolk mottling.

A variation was also found in the percent of consumers preferring eggs with less yolk mottling at each of the preference panel locations. A higher percent of consumers in the Athens location preferred eggs with less mottling than did consumers in the Detroit location. Slight variations in samples shown consumers at each of the locations could account for the difference. This variation, however, was not statistically significant at the one percent level of significance.

Due to the data obtained from these two consumer preference panels and the data obtained by Blackshear et al. (1967b), it is recommended that the United States Standards for Quality of Individual Eggs should be revised to include mottling in quality determination.

Experience of the author has shown that eggs with

mottled yolks usually are downgraded by processors and buyers. Interior egg quality is determined by a process called candling. Expert candlers can detect yolk discoloration if the yolk shadow is clearly visible. However, small shadows cast by the chalazae are sometimes confused with yolk mottling.

Many egg processors are operating on the U.S.D.A. Fresh Fancy Program. This requires breaking a sample of eggs to determine interior quality. Mottling is easily detected in broken-out eggs, and results in downgrading or a lower quality classification.

The United States Standards for Quality of Individual Shell Eggs states that in Grade AA and Grade A eggs, the yolk must be practically free from apparent defects. In Grade B eggs the yolk may appear slightly emerged or slightly flattened and may show other definite, but not serious defects. The yolk of Grade C eggs may show other serious defects that do not render the egg inedible.

The description that is given for the phrase "practically free from defects," is a "yolk that shows slight defects on its surface." Eggs meeting these qualifications fall into the Grade AA or A quality classification. "Definite but not serious defects" is defined as a "yolk that may show definite spots or areas on its surface but with only slight indications of germ development or other pronounced or serious defects." The phrase

"other serious defects" which is included in the specifications for Grade C is defined as a "yolk that shows well-developed spots or areas and other serious defects, such as an olive yolk, which do not render the egg inedible."

The phrases used to describe the degree of defects permitted in each grade classification are very vague and confusing. It is difficult if not impossible to classify eggs with these yolk defects with any degree of consistency.

The data obtained by Blackshear et al. (1967b) indicated that 56.07 percent of all fresh eggs examined in the Georgia study were mottled to some degree. After 28 days of storage the incidence had increased to 69.72 percent. Because of the tremendous amount of egg yolk mottling that apparently is occurring and because of the vagueness of the terms employed to describe the standards for quality, it is proposed that the findings obtained in this study be incorporated into the U.S.D.A. Standards for Quality for Individual Eggs.

The results of this study indicate that moderate mottling, often appearing as swirls or undulate shape, covering 5 to 15 percent of the exposed yolk surface appears to be the breaking point for consumer acceptance of eggs having mottled yolks. If consumers do not reject eggs with yolk mottling of this degree or less, then it is recommended that this level or degree of mottling should be permitted in the U.S.D.A. AA and A grade classification.

This would provide egg graders with information that would be of assistance in grading eggs with yolk defects more uniformly and consistently.

It is recommended that mottling covering from 15 to 60 percent of the exposed yolk surface should fall into U.S.D.A. Grade B while mottling covering 60 - 100 percent of the exposed yolk surface should be classified as U.S.D.A. Grade C.

SUMMARY

Egg yolk mottling is often a serious economic problem to the poultry industry as eggs having mottled yolks are downgraded by egg buyers and/or processors. This condition is receiving renewed attention as many housewives supposedly believe that eggs with mottled yolks are either spoiled or of low quality.

Yolk mottling is apparently caused by movement of water and egg white protein from the albumen of the egg through the vitelline membrane into the yolk. Mottled yolks contain spots or blotches of different colors or shades of color which vary in size and number from egg to egg. The mottled yolk contains more water, more egg white protein and a higher protein fat ratio than does a control egg.

Eggs produced by most laying flocks have a limited amount of "natural" mottling. The intensity of "natural" mottling is apparently low. Most poultrymen believe it is seldom serious enough to cause consumer complaints. A review of literature revealed that very little information was available on consumers' reactions to mottled yolks.

This investigation was concerned with consumer acceptance of yolk mottling and consumer reaction to

varying degrees of mottling. The level or degree of mottling at which consumers reject eggs and the effect of various demographic factors such as age, education, income and geographic location on consumer preference for mottled yolks was analyzed.

Consumer preference data were collected through the use of consumer panels. Consumer preference panels using the appearance test were conducted in Detroit, Michigan and Athens, Georgia. These panels were designed to determine preferences of consumers with annual incomes ranging from under $2,000 to over $10,000, of ages from under 30 to over 60 years, and with 0 to 14 years of formal education. A paired-comparison test was used whereby each untrained panel member was presented two coded samples and asked to compare them.

A six-point scale was used to assess the degrees of mottling with each point representing a different degree of mottling. The method of paired-comparisons employing unequal repetition of pairs was used to determine overall preference of samples.

Results of the six treatments used in the Athens panel indicate no significant difference in preference with a pairing of Sample 1, no visible yolk mottling and Sample 2, slight mottling. No significant difference in preference was also indicated between Sample 1, no visible mottling, and Sample 3, moderate mottling and

between Sample 2, slight mottling, and Sample 3, moderate mottling. In all other possible pair-combinations the sample with the lesser degree of mottling was preferred. These preferences were significant at the one percent level of probability.

Multiple range test analysis revealed that Sample 1 and Sample 2 (no visible mottling and slight mottling) were similar to each other. They were, however, not significantly different from Samples 2 and 3 (slight mottling and moderate mottling) which were also similar to each other. No significant difference was found between Samples 1, 2, and 3 (no visible yolk mottling, slight mottling and moderate mottling).

In the Detroit panel, Sample 2, slight yolk mottling, was chosen over Sample 1, no visible mottling. Sample 1, no visible mottling, however, was selected by consumers over Sample 3, moderate mottling. Duncan's multiple range test analysis revealed no significant difference between Samples 1 and 2, however, there was a significant difference between Samples 1 and 3 at the five percent level. In all other possible pair combinations, samples with less mottling were preferred.

Analysis of various demographic factors such as age, education, income and location revealed that these factors had relatively little influence on consumer preference for mottled egg yolks. Although some differences

were found, the amount of variation was too small to be statistically significant.

These studies indicate that consumers do not notice mottling at low levels and that "natural" mottling is not usually severe enough for most consumers to notice. Sample 3, moderate mottling covering five to fifteen percent of the exposed yolk surface, was found to be the breaking point for consumer acceptance of eggs having mottled yolks. Mottling above this level (Sample 4, 5, and 6) was found to be objectionable to consumers.

It is recommended that the United States Standards for Qaulity of Individual Eggs be revised to include yolk mottling in quality determination. Since consumers apparently do not reject eggs with slight and moderate yolk mottling, this level or degree of mottling should be permitted in the U.S.D.A. Grade AA and Grade A classification. Mottling covering from 15 to 60 percent of the exposed yolk surface should be classified as U.S.D.A. Grade B while mottling covering 60 to 100 percent of the yolk surface should be classified as U.S.D.A. Grade C.

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