EFFECT OF EGG PRODUCTS ON THE TEXTURE OF PASTA MADE FROM OKLAHOMA HARD RED WINTER WHEAT

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CHAPTER I

INTRODUCTION

As Americans become increasingly concerned with their overall health, one of the main areas targeted for change is diet. The United States Departments of Agriculture and Health and Human Services (1980) developed a set of dietary goals and guidelines aimed at limiting the consumption of fats, especially saturated fats, and cholesterol. Along with this recommendation, they have also suggested increasing the amount of complex carbohydrate in the diet while decreasing simple carbohydrates such as refined sugars.

As a result of the "menu revolution" as suggested by Adams (1987), brought on by these goals and guidelines, one of the food products that has gained wide acceptance and popularity is pasta, an excellent source of complex carbohydrate. Whether used fresh or in the more widely available dried form, pasta is eaten extensively in salads, side dishes, and entrees as part of an overall nutritionally balanced diet. This is evident in that pasta comsumption by Americans is more than 14.7 pounds per person per year (an increase of 19.8% from 1975 to 1984) according to Heilman and Wilson (1988).

On the production side, Oklahoma farmers produce 172.8 million bushels of Hard Red Winter (HRW) wheat (*Triticum aestivum*) annually at a value of $622 million, making wheat the second largest farm commodity produced by the state, and the largest agricultural crop as reported by the Oklahoma Agricultural Statistics Service (1988). This wheat is made primarily into flour, and virtually none is used in pasta production. Most of the wheat is exported from the state as a raw commodity and then imported back as value-added food products. The development and manufacture of pasta in Oklahoma should be economically beneficial by keeping the value added revenue in the local economy.

Researchers in the Department of Food, Nutrition, and Institution Administration Department of the College of Home Economics at Oklahoma State University are formulating pasta partially or completely prepared from Oklahoma HRW wheat. The developed fresh (undried) pasta has been rated acceptable in sensory evaluations for texture, flavor, and overall acceptability (Stokes et al., 1991). Current work is targeted toward developing consumer acceptable dried pasta products that are resistant to breakage, vitreous in appearance, shelf stable, and maintain acceptable texture quality over time.

Egg is an ingredient in the pasta recipe used. While not a necessary ingredient in pasta production, eggs are often added to pasta to enhance flavor and nutritional quality (Antognelli, 1980). However, it is not known whether egg affects the firmness or texture of fresh or stored dried pasta. If a high quality pasta is to be manufactured, it is important to investigate the roles of whole eggs and egg components in fresh pasta and in dried pasta over time.

Purposes and Objectives

The purpose of this study is to determine the effects of whole egg, fresh egg white, dried egg white, fresh egg yolk and no added egg on the texture and storage life of the experimental pasta made from HRW wheat.

The objectives of the study are as follows:

1. To determine the effect of egg and egg components on the texture of fresh raw pasta.

2. To determine the effect of egg and egg components on the texture of freshly cooked pasta.

3. To determine the effects of egg and egg components on the texture of the boiled, dried pasta after two, four, six, eight, and ten weeks of storage.

4. To obtain analytical data on the flours used and the treatment formulations.

Hypotheses

The following hypotheses were postulated for this research:

H_1: There is no difference in the texture of freshly made raw pasta due to the presence of whole egg, egg yolk, egg white (fresh or dried) or no egg in the formulation.

H_2: There is no difference in the texture of freshly made boiled pasta due to the presence of whole egg, egg yolk, egg white (fresh or dried) or no egg in the formulation.

H_3: There are no changes in the texture of the boiled, dried pasta after two, four, six, eight, and ten weeks of storage due to the presence of whole egg, egg yolk, egg white (fresh or dried) or no egg in the formulation.

Assumptions and Limitations

The following assumptions were made for this study:

1. A single batch of blended varieties of Oklahoma HRW wheat, obtained from Shawnee Milling company, Shawnee, OK, used throughout this study was a typical sample of Oklahoma HRW wheat.

2. A single batch of durum semolina obtained from North Dakota Mill and Elevator, Grand Forks, ND, used in the reference formula in this study was typical of all durum semolina.

Limitations for this study were identified as follows:

1. Six pasta formulary were investigated:

   a. 1360.8 g. hard red winter (HRW) flour, 482.2 g. water.

b. 1360.8 g. HRW flour, 340 g. fresh egg white, water to equal 482.2 g. total liquid.

c. 1360.8 g. HRW flour, 40.4 g. dried egg white powder, 482.2 g. water.

d. 1360.8 g. HRW flour, 340 g. fresh egg yolk, water to equal 685 g. total liquid.

e. 1360.8 g. HRW flour, 340 g. fresh whole egg, water to equal 585 g. total liquid.

f. 35% HRW/65% durum semolina blend to equal 1360.8 g. total flour, 340 g. fresh whole egg, water to equal 585 g. of total liquid.(This was the original recipe used and was carried as an internal control in this laboratory throughout this and other experiments in the on-going pasta research.)

2. The pastas were dried in temperature (but not humidity) controlled forced air dryer.

3. Texture ratings for this study are solely based on readings obtained from the Food Technology Corporation TG4C Texturegage equipped with a single blade shear cell.

Definition of Terms

The following are the definition of terms used in this study:

Egg Albumin. Frequently referred to as the "white" of an egg. It consists mostly of protein and water with only a small amount of carbohydrate and just a trace of fat (Campbell et al., 1979).

Al Dente. "To the tooth." Firm, not soft or mushy, to the bite (Gisslen, 1983).

Checking. Cracking that occurs in dried pasta when moisture gradients are formed in pasta that is dried too quickly (Hahn, 1990).

Durum. *Triticum durum*. A variety of wheat typically yellow in color, high in protein, and used in the Americas and Europe almost exclusively in the production of pasta and macaroni products (Fabriani and Lintas, 1988).

Emulsify. Cause fats to remain suspended in a watery medium (Freeland-Graves and Peckham, 1987).

Gluten. A three-dimensional complex of hydrated protein in which starch grains are embedded. It is developed by kneading or stirring (Freeland-Graves and Peckham, 1987).

Hard Red Winter Wheat. *Triticum aestevum*. A type of wheat grown throughout the great plains, planted in the fall and harvested in late spring. It has a redish colored bran coat, but yields a white flour which is medium high in protein (typically 9-14%) and is widely used for bread making and all purpose flour (Freeland-Graves and Peckham, 1987).

Lecithin. A naturally occurring emulsifier and is the main phospholipid found in egg yolk (Charley, 1982).

Pasta. Macaroni products made from semolina, durum flour, farina, flour, or any combination of two or more of these with water. Optional ingrediants may include vitamin and mineral enrichment, egg products, and other protein enrichments (Food and Drug Administration, 1987).

Semolina. A high protein fraction ground from the inner parts of durum wheat kernels (Gisslen 1983). The endosperm fraction remaining on top of a U.S. No. 100 sieve (Fabriani and Linlas, 1988).

Texture. The response of the tactile senses to physical stimuli that result from contact between some part of the body and food (Bourne, 1982).

Vitreous. Glassy or resembling glass in appearance (Funk and Wagnalls, 1966).

Yolk. The "yellow"" part of the egg. The yolk contains fat, cholesterol, lecithin, protein, and less water than the white (Campbell et al., 1979).

Statement of Format and Style

This thesis follows the standard five chapter form suggested by the Graduate College with the exception of Chapter six which is a separate article. This article follows the format guidelines of the Journal of Food Quality. The style and format of the thesis and included article follow the format for citations and literature required by the Journal of Food Quality.

CHAPTER II

REVIEW OF LITERATURE

History and Definition of Pasta

Pasta manufacture and consumption originated many centuries ago and may have had beginnings in the early Mediterranean areas according to Antognelli (1980). The specific date and birthplace of pasta is not known, but many early civilizations have been attributed to having some form of pasta product in their diets including early China, Java, Greece, and Arabia (Antognelli, 1980; Bozzini, 1988; and Adams, 1987). The word "pasta" is a term that can be used to identify any combination of flour and water that can be rolled, pressed or extruded into desired shapes. Also the name "pasta" can be used to refer to either a freshly made product or the more common dried, shelf-stable product.

Though there are no federal regulations concerning fresh pasta manufacturing, the Food and Drug Administration (FDA, 1987) does regulate the ingredients in dried pasta, more specifically referred to as macaroni and noodles. These requirements are that macaroni products be made from semolina, durum flour, farina, flour, or any combination of two or more of these with water. The specifications go on to include a list of optional ingredients that may be added in specified amounts to enhance the desired properties. These ingredients include egg white, frozen egg white, dried egg white, disodium phosphate for "quick cooking," onion, celery, garlic, bay leaf, or salt for seasoning, gum gluten and glyceryl monostearate.

Other ingredients may be added for enrichment and fortification proposes. Thiamine, riboflavin, niacin (or niacinamide), and iron are all added by law to enriched products; but vitamin D and calcium may also be used. Protein fortification of pasta is also permissible by the use of casein, soy, milk and nonfat milk, dried yeast, dried torula yeast, and partially defatted wheat germ (FDA, 1987).

Pasta Drying

Dried pasta products are desirable due to ease of storage and long shelf life. Other factors include low cost, versatility, and ease of preparation (Cummings, 1983). Pasta products have been dried for centuries, from the time they were first produced, as indicated by Antognelli (1980), who states that the weather conditions and geographic location of Italy was ideally suited for natural pasta drying.

Today the process of drying pasta is much more complicated. Antognelli (1980) describes the drying process as three-fold, with pre-drying, sweating, and drying all under strict temperature and humidity controls to prevent checking. Hahn (1990) indicated the method for drying pasta products depends on the size and shape of the product after extrusion. Hahn also mentions alternate methods of drying including high temperature drying and microwave drying and stresses the importance of temperature control, but controls on humidity are indicated. In their studies on durum wheat protein and spaghetti quality, Dexter and Matsuo (1980) specified a temperature for drying pasta and recommended humidity control without specifying a level. This was also seen in the later work of Dexter et al. (1983). It should be noted that while some type of temperature and humidity control are often suggested for pasta made of durum wheat, Chinese and Japanese noodles are often dried without humidity control and are generally not made of durum wheat as indicated by Lii and Chang (1980).

In summary, in reviewing the material covered, the first objective to drying pasta is to reduce the initial moisture content of approximately 28-30% to prevent spoilage. The final stages of drying provide for equilibrium of moisture throughout the product and reduce the final moisture content to about 12-14%, which gives shelf stability.

Measurements of Pasta Quality

Much research is dedicated to producing a high "quality" pasta without being specific as to what characteristics contribute to quality pasta. A consensus may be drawn, however, that suggests quality pasta is firm, resilient, and not sticky (Dexter et al., 1985). Researchers have examined various mechanical and analytical tests to measure or predict the quality of pasta made from durum, including different varieties of durum, and other grain and non-grain flour sources such as corn, soy, rice, and bean starches.

One area of focus has been the role of gluten in pasta. Haber et al. (1978), Feillet et al. (1989), Schofield (1983), Dexter and Matsuo (1980), and Pomeranz (1971) all indicate that gluten (both quality and amount) is important to the final quality of the pasta produced. The gluten is assessed by various methods including Kjeldahl determination by Dexter and Matsuo (1980); solvent extraction, ion-exchange chromatography, and densitometry of gel electrophoresis patterns by Feillet et al. (1989); and by assessing dough rheology by Haber et al. (1978).

Other indicators for pasta quality have been examined. Dexter et al. (1985) evaluate pasta quality in terms of stickiness by evaluating total organic material losses and compression tests. Kushnir et al. (1984) focuses on gliadin proteins as an indicator of quality by using polyacrylamide gel electrophoresis to characterize grain gliadin protein. Still other researchers diverge completely and decide that color is a chief factor in determining pasta quality. Johnson et al. (1980) and Palvolgyi et al. (1982) both examined the color of pasta while Palvolgyi et al. (1982) has devised an assessment tool in the form of a diagram that rates color by a yellow index (YI) and pasta "endurance" by a color value (CV) index using aleurograph.

Dough rheological characteristics, and ultimately pasta quality, may also be examined by farinograph curves, gluten stretching tests, extensographs, and mixograph curves according to Bourne (1982) and Hahn (1990). The final texture of the cooked product may also be evaluated by measuring pasta breaking strength using mechanical means such and the Food Technology Corporation Texture Test System, Instron or by sensory evaluation as explained in the work of Bourne (1982), Pomeranz (1971), and Dick and Youngs (1988). Much work has been done in examining the use of instrumental texture measurement for evaluating organoleptic qualities of food products in general as demonstrated by Frost et al. (1984), Stanley (1986), and Kokini (1985). This proves to be a very promising area for examining the quality of food products but; as pointed out by Peleg (1983), no single measure of quality is without faults and should be used in conjunction with other testing procedures.

Role of Egg in Food Products

Eggs are a combination of proteins, primarily albumin, fats, carbohydrates, minerals, vitamins and pigments as described by Freeland-Graves and Peckham (1987). Eggs are used in food products for nutrient fortification purposes, for the addition of desirable flavors and colors, and for special effects of emulsification on other ingredients in food products. Eggs can also be easily divided into two separate parts, the "white" and the "yolk." Each will be discussed separately and as the whole egg in this review. (A comparison of the nutritive values of egg yolk, egg white, and whole egg is provided in Appendix A.)

Egg Yolk

Egg yolk consists roughly of 50% water with the other 50% solids. Solids are about 33% protein, made up of vitellin, phosvitin and livetin, and 67% fat made of triglycerides, phospholipids (mostly lecithin), and cholesterol (Charley, 1982). Because of this balance of nutrients, egg yolk is an excellent emulsifier and tenderizing agent. This is demonstrated by Charley (1982), Campbell et al. (1979), Freeland-Graves and Peckham (1987), and Baldwin (1986). In research on whole wheat bread quality, Finney et al. (1985) determined that use of egg yolk increased bread loaf volume.

Egg White

Egg white is primarily water (approximately 88%) and proteins consisting of ovalbumin, conalbumen, and ovomucoid. Egg white is valued in food production for its foaming ability (Charley, 1982; Campbell et al., 1979; Freeland-Graves and Peckham, 1987; and Baldwin, 1986). In addition, egg whites are viscous, with the viscosity being temperature dependant as shown in research by Pitsilis et al. (1984).

Ma et al. (1986) attribute the properties of foaming, emulsification, and heat coagulation to egg white. Ball (1987) also indicates that egg whites function well as foams, gels and emulsions. In earlier work Ball and Garder (1968) reported these same properties but with irradiated egg whites.

Whole Egg

Generally eggs coagulate with heat and provide structure and stability as well as thickening and binding (Charley, 1982; Campbell et al., 1979; Freeland-Graves and Peckham, 1987; and Baldwin, 1986). Heath and Owens (1984) find that eggs expand when heated. Toney and Berquist (1983) also illustrate these characteristics.

Role of Flour in Food Products

Flours are produced from a number of grains such as wheats, rye, corn, and sorghum, and in small quantities produced from other sources such as barley, rice, potato, cassava, soybean, and peanuts according to Freeland-Graves and Peckham (1987). Most flour manufactured for commercial and home use, and more specifically pasta, is produced from wheat, therefore, most of the discussion in this review will be limited to wheat flours, primarily common *triticum aestevum* or "bread" flour and *triticum durum* or durum flour. It should be noted here that some pasta products are made from other sources such as corn flour, according to Molina et al. (1975), red bean starch, according to Lii and Chang (1980) and corn, rice and/or casava according to Sheuy et al. (1977).

Common Wheat Flour

Wheat for flour is classified as either spring or winter wheat, depending upon the time that the grain is planted and harvested, according to Campbell et al. (1979). Wheat may also be classified as either "hard" or "soft" depending upon the protein content of the wheats with hard wheats having a higher protein content and a harder kernel (Freeland-Graves and Peckham, 1987). This becomes important later when the wheat is ground and refined into the different types of flour including (but not limited to) bread flour, cake flour, and pastry flour, each of which depends upon a specific protein content to provide necessary characteristics (Campbell et al. 1979).

Regular Wheat Flour Characteristics

Flour is valued in baked goods due to its combination of starch and protein. Starch allows the food product to absorb fluid, and the protein allows the food product to retain structure. The protein referred to here is primarily gluten. Gluten is "developed" in products by kneading or agitation of a flour dough and forms a rigid structure during baking. It is this rigid structure that is desired in baked products because of its ability to hold the carbon dioxide gas that is responsible for the "rising" of these baked products (Charley, 1982; Campbell et al., 1979; and Freeland-Graves and Peckham, 1987). While used mostly in baked products, wheat, and more specifically hard red winter wheat, has been used in making Chinese and Japanese noodles as seen in the works of Oh et al. (1985), Toyokawa et al. (1989), and Preston et al. (1986). Kim et al. (1986 and 1989) produce pasta in the form of spaghetti from HRW. Dexter and Matsuo (1978) also make pasta from hard red spring wheat while Magnuson (1985) indicates pasta may be made from non-durum wheat, but suggests supplementing pasta with gluten. Fernandes et al. (1978) is concerned with flour particle size for effective pasta production from "bread" wheat.

Durum Flour (Semolina)

Confusion may arise when discussing bread flours and durum flours. Durum flours also contain gluten and a "strong" gluten is desirable when making pasta (Feillet, 1988). However, the gluten in durum flour has a different composition than the gluten in regular wheat flour. "In particular, a high proportion of glutenins among the gluten proteins appears to be a prerequisite for the production of superior quality pasta," according to Dexter and Matsuo (1978). They further state that durum wheat flour produces pasta with superior color (yellow) and cooking qualities. Actually, pasta is generally made of durum semolina which is a larger particle size (488 - 142*u*) than flour, and "mixing only wets the semolina particles but does not significantly change the microstructure," as stated by Hahn (1990). Therefore, it is assumed that the development of "gluten" as is done in the kneading of regular wheat flour for bread is not a factor in pasta quality. However, the role of the protein fractions, particularly the glutenins among the gluten proteins appears to be very important for quality pasta according to Dexter and Matsuo (1978).

In conclusion, almost all of the research done with durum wheats is aimed toward pasta production. Durum flours have been made into other products including fortified pasta according to Banesik and Dick (1982). Quaglia (1988) has review the use of durum in bread, conscious, instant noodle snacks, and bulgur.

CHAPTER III

MATERIALS AND METHODS

Pasta Dough Preparation for Fresh and Dried Pasta

The six pasta formulations were produced from a single lot (500 lbs) of flour milled from blended varieties of Oklahoma HRW wheat, obtained from Shawnee Milling Company, Shawnee, OK, who described the flour lot as a typical sample of Oklahoma HRW wheat flour. A single batch of durum semolina from North Dakota Mill and Elevator, Grand Forks, ND, was used as a typical sample of durum semolina. The water used for the liquid in each formulation was local tap water with no distillation or deionization treatments. Egg products used for this study included USDA grade A eggs obtained from a local market with the exception of the dried egg white which was obtained from a commercial producer. For the purpose of this study, investigations were limited to the following formulations:

1. 1360.8 g. hard red winter (HRW) flour, 482.2 g. water.
2. 1360.8 g. HRW flour, 340 g. fresh egg white, water to equal 482.2 g. total liquid.
3. 1360.8 g. HRW flour, 40.4 g. dried egg white powder, 482.2 g. water.

4. 1360.8 g. HRW flour, 340 g. fresh egg yolk, water to equal 685 g. total liquid.

5. 1360.8 g. HRW flour, 340 g. fresh whole egg, water to equal 585 g. total liquid.

6. 35% HRW/65% durum semolina blend to equal 1360.8 g. total flour, 340 g. fresh whole egg, water to equal 585 g. of total liquid. (This was the original recipe used and was carried as an internal control in this laboratory throughout this and other experiments in the on-going pasta research.)

All ingredients were weighed using a Fisher Scientific XT top loading balance. Ingredients were combined in the mixing hopper of a La Parmigiana Model D45 single screw extruding pasta machine and kneaded for seven minutes. After kneading, the doughs were extruded through a shell-shaped die. Random samples of shells from each of the doughs were saved for texture testing of fresh uncooked and fresh cooked product. Samples were also taken for later chemical analysis. The remaining pasta shells were blanched by immersing the shells in boiling water and immediately removing them from the water. The shells were then placed in cold water to stop the cooking process. The shells were then dried in food dehydrators at an initial "high" temperature of 145°F for 56 hours to prevent spoilage and to speed drying (Hahn, 1990). This was followed by a final drying and holding at a lower temperature of 90°F. There were no humidity controls on the dryers. After two weeks the pasta shells were placed in labeled polyethylene bags to prevent changes due to atmospheric conditions. The entire study was replicated three times.

Preparation of Pasta for Texture Measurements

Uncooked Pasta Shells

Uncooked pasta shells (about 50 shells from each formula) were sealed in labeled polyethylene bags immediately after extrusion and were held refrigerated at 2°C for approximately 24 hours to allow for moisture equilibration throughout the uncooked pasta shells and then measured for texture. These shells received no further treatment.

Samples to be Tested After Boiling

Samples to be tested after boiling were cooked to the "al dente" stage in boiling water, plunged in cold water to halt the cooking process, and drained. For this research, "al dente" is defined as the point where a thin line of uncooked starch remains in the interior of the pasta shell after cooking. The shells were then placed in labeled, sealed polyethylene bags to prevent drying. All of the fresh cooked pasta shells reached the "al dente" stage after only two minutes in boiling water.

Samples to be Tested After Drying

For samples to be tested after drying, about 50 dried shells of each of the pasta treatments were taken at two week intervals and boiled for texture analysis. Some of the dried formulations required different times to reach the "al dente" stage. As was expected, the dried pasta required longer boiling time than the fresh pasta to reach the "al dente" stage; but, even within the dried pasta, the different formulations required different boiling times as seen below:

No Egg	12 minutes
Fresh Egg White	13 minutes
Dried Egg White	14 minutes
Fresh Egg Yolk	13 minutes
Whole Egg	13 minutes
35/65 Whole Egg	14 minutes

As with the fresh cooked pasta, these shells were cooked in boiling water, plunged in cold water, drained, and placed in labeled and sealed polyethylene bags until texture analysis could be completed (about 18 to 24 hours).

Chemical Analysis

Samples of the HRW wheat flour and durum semolina were analyzed for moisture, protein, ash contents, and mixograph characteristics. Samples of uncooked shells from each of the six pasta treatments were also analyzed for moisture, protein and ash. All these tests were conducted in the Oklahoma State University Wheat Quality Laboratory. Moisture content was determined by using the modified two-stage air oven method according to AACC Method 44-18 (1962). Crude protein was determined by using the Kjeldahl method with boric acid modifications according to AACC method 46-12 (1962). Ash content was determined using a five gram sample of approximately 13% moisture. Mixograph characteristics of the HRW flour and semolina were determined by the standard procedures followed in the Wheat Quality Laboratory and described by Elaison (1990). (For more details see Appendix A.)

Fragmentation

In previous research at Oklahoma State University, pasta that was dried after extruding tended to break into fragments when eventually cooked. In order to monitor similar checking and fragmentation in the dried HRW pasta formulations, a visual scale rating the amount of fragmentation from none to extreme was used to monitor this after shells from each pasta formulations were boiled. The scale was numerical from zero to 10, with zero representing no observed damage, and 10 representing 35 or more damaged shells.

Texture Analyses Procedure for All Treatments

A Food Technology Corporation TG4C Texturegage (Bourne, 1982) equipped with a single blade shear was used to analyze texture of the six pasta formulations. Ten sets of samples (in sets of one and three pasta shells) from each formulation were placed across the platform of the machine and the shear blade was lowered. The maximum number recorded by the Texturegage represented the force in pounds required to break through the pasta shells with a higher number representing firmer texture. For analyses of both series (the sets of one-shell and sets of three-shell cuts) see Appendix B.

Statistical Analyses of Texture Data

This experiment followed a nested Analysis of Variance (ANOVA) design with F-tests to determine the existence of significant differences; Duncan's Multiple Range (DMR) tests identified these differences. An alpha level of 0.05 was established. Ten pasta shells and ten sets of three pasta shells were cut from each replication for each formulation; and for the dried pasta, this was done at two-week intervals. The entire study was replicated three times for a total of 210 cuts in the one-cut series and 630 cuts in the three-cut series. (For more details see Appendix B.)

CHAPTER IV

RESULTS AND DISCUSSION

These data were analyzed in two separate series, data from single shell cuts and from three-shell cuts. Data from the single shell cut series will be presented first.

Single Cut Texture Series

Single shells of each of the six different pasta formulations were cut by a single shear blade with the resulting numbers representing the force required (in pounds) to break through the noodles. A higher reading indicated a firmer texture for pasta.

Single Cut Data of Fresh Pasta

Table I shows the mean results for texture of the fresh uncooked pasta shells. These mean values represent three separate replications of 10 individually cut pasta shells.

These data for uncooked fresh pasta do not appear to indicate any clear pattern, but it is noted that the egg yolk pasta was the most tender, but not statistically different from three of the other pasta treatments. After cooking, as expected, the pasta shells were much softer. The order of firmness also changed for some pasta treatments. Table II below represents the mean values for the fresh cooked pasta shells.

TABLE I

MEAN SHEAR FORCE RATINGS FOR FRESH UNCOOKED PASTA SHELLS SINGLE CUT SERIES

TREATMENT	SHEAR FORCE (lbs)*
HRW Fresh Egg White	13.4 A**
Durum/HRW Whole Egg	9.8 B
HRW No Egg	9.2 BC
HRW Dried Egg White	9.0 BC
HRW Whole Egg	7.6 BC
HRW Egg Yolk	6.0 C

*As measured by Food Technology Texture System
**Means with the same letter are not significantly different

TABLE II
MEAN SHEAR FORCE RATINGS FOR FRESH COOKED PASTA SHELLS SINGLE CUT SERIES

TREATMENT	SHEAR FORCE (lbs)*
Durum/HRW Whole egg	3.8 A**
HRW Fresh Egg White	3.6 A
HRW Dried Egg White	3.2 AB
HRW Whole Egg	2.9 B
HRW No Egg	2.8 B
HRW Egg Yolk	2.1 C

*As measured by Food Technology Texture System
**Means with the same letter are not significantly different

Again, the egg yolk pasta was still the most tender; and in this data, it was significantly more tender than the other formulations. Upon cooking, the egg yolk pasta developed a "mushy" surface and "slimy" characteristics that the researchers considered unacceptable. After cooking, the durum containing pasta was the firmest though not significantly firmer than the egg white pasta.

Single Cut Data of Dried Pasta

The dried pasta shells were sampled every two weeks for 10 weeks. The mean values for these data were obtained from three separate replications of 10 shells each. As seen in Table III, the mean texture values for the dried cooked pasta did not exhibit a great difference from those for the fresh cooked pasta. The 65% durum was the firmest, the egg white pasta next, followed by the whole egg and no egg pasta. The egg yolk was the most tender at each test period. However, by six weeks there were fewer significant differences; and, after six weeks, there were no significant differences among any of the pasta treatments. The egg yolk pasta was no more acceptable after drying than fresh; it tended to become mushy on the exterior, while still containing uncooked starch on the interior.

TABLE III

MEAN SHEAR FORCE RATINGS FOR DRIED COOKED PASTA SHELLS SINGLE CUT SERIES

	2 wks	4 wks	6 wks	8 wks	10 wks
D/HRW Whole Egg	3.4 A*	3.1 A	3.0 A	2.7 A	2.7 A
HRW Fresh White	3.0 AB	2.8 AB	3.0 A	2.7 A	2.4 A
HRW Dried White	2.7 BC	2.6 ABC	2.6 A	2.5 A	2.4 A
HRW Whole Egg	2.9 ABC	2.2 BCD	2.2 AB	2.2 A	2.1 A
HRW No Egg	2.3 CD	2.1 CD	2.0 AB	2.1 A	1.8 A
HRW Egg Yolk	1.8 D	1.6 C	1.5 B	1.6 A	1.6 A

*In columns, means with the same letter are not significantly different

Three-Cut Texture Series

The results of the three-cut pasta shell series were somewhat similar to the single-cut series for the fresh uncooked shells (see Table I). The egg yolk pasta was least firm and the fresh egg white most firm, but there were few other similarities between the two sets of uncooked pasta data. The higher numbers in Table IV (as compared to Table I) represent the increased force necessary to cut through three pasta shells as opposed to cutting a single shell.

Three Cut Data of Fresh Cooked Pasta

The results for the fresh cooked pasta using three cuts were similar to those of the single cuts (Table II) with the egg yolk pasta being significantly less firm than the other pasta treatments. With these data, however, the durum containing pasta was firmest, but not significantly firmer than either of the egg white formulations as seen in Table V.

TABLE IV

MEAN SHEAR FORCE RATINGS FOR FRESH UNCOOKED PASTA SHELLS THREE CUT SERIES

TREATMENT	SHEAR FORCE (lbs)*
HRW Fresh Egg White	30.8 A
HRW Dried Egg White	24.1 AB
Durum/HRW Whole Egg	23.7 AB
HRW No Egg	22.9 B
HRW Whole Egg	18.4 BC
HRW Egg Yolk	15.2 C

*As measured by Food Technology Texture System

**Means with the same letter are not significantly different

TABLE V

MEAN SHEAR FORCE RATINGS FOR FRESH COOKED PASTA SHELLS THREE CUT SERIES

TREATMENT	SHEAR FORCE (lbs)*
Durum/HRW Whole Egg	9.6 A
HRW Fresh Egg White	9.2 A
HRW Dried Egg White	8.8 A
HRW Whole Egg	6.6 B
HRW No Egg	6.5 B
HRW Egg Yolk	4.8 C

*As measured by Food Technology Texture System

**Means with the same letter are not significantly different

Three Cut Data of Dried Pasta

The mean texture measurements for the three-cut dried pasta shells were similar to that of the single cut dried pasta (Table II) until the eighth week of storage when the durum containing pasta was no longer the firmest. In the eighth week, with three cuts, the dried egg white pasta was firmest and egg yolk softest, as with the single cuts, but there were no significant differences among any other treatments. The means of the tenth week vary from that expected from the single cut data where there were no significant differences among any of the treatments. With three cuts, differences could be detected. As seen in Table VI, the egg yolk pasta was significantly less firm than either the dried egg white pasta or the durum containing pasta.

TABLE VI

MEAN SHEAR FORCE RATINGS FOR DRIED COOKED PASTA SHELLS THREE CUT SERIES

	2 wks	4 wks	6 wks	8 wks	10 wks
D/HRW Whole Egg	8.0 A*	7.2 A	7.2 A	6.3 A	6.6 A
HRW Fresh White	7.7 AB	6.8 A	7.2 A	5.7 A	5.7 AB
HRW Dried White	6.8 AB	6.5 A	6.6 AB	6.9 A	6.2 A
HRW Whole Egg	6.5 B	5.3 B	5.9 AB	5.7 A	5.2 AB
HRW No Egg	5.1 C	4.7 B	5.3 BC	4.7 A	4.7 AB
HRW Egg Yolk	4.0 D	3.6 C	3.8 C	3.9 A	3.6 B

*In columns, means with the same letter are not significantly different

Fragmentation of Dried Pasta

Firmness ratings alone do not show the quality of the product. Close inspection of the dried shells showed very faint fracture lines in most of the dried shells after only two weeks. After boiling, these became more apparent. Over time this cracking increased, and the shells started to fragment. This was most apparent in the dried egg white pasta. Table VII reports the observed fragmentation in all dried pasta formulations.

TABLE VII

OBSERVED CRACKING AND FRAGMENTATION

	2 wks	4 wks	6 wks	8 wks	10 wks
D/HRW Whole Egg	-	-	-	*	*
HRW Fresh White	-	-	*	*	**
HRW Dried White	*	**	***	***	***
HRW Whole Egg	-	-	*	*	***
HRW No Egg	*	*	*	*	**
HRW Egg Yolk	#	#	#	#	#

-	Slight to moderate cracks but no fragmentation
*	Most shells showing cracks with a few fragmented
**	Approximately 20-30% of shells were fragmented
***	More than 50% of shells were fragmented
#	Unacceptable because of crumbling

According to literature, pasta that dries too rapidly on the surface (case hardening) may check as the trapped interior moisture escapes resulting in cracking along these checking lines (Antognelli, 1980). This tendency reportedly increases over time. Commercially case hardening is controlled by maintaining a high level of humidity in the drying ovens, especially during the high temperature drying stage. The lack of humidity controls on the driers used in this study may account for the checking and fragmentation of the dried pasta.

Analyses from Wheat Quality Laboratory

In comparing HRW flour and durum semolina, the durum was higher in protein than the HRW and contained more ash. Increased ash content in flour generally indicates a poor quality bread wheat (Pomeranz, 1971). Mixograph data indicated that the durum absorbed less water than the HRW flour, mixed more rapidly, and had a poorer tolerance to overmixing as seen in Table VIII.

TABLE VIII
WHEAT QUALITY LABORATORY ANALYSIS OF HRW FLOUR AND DURUM SEMOLINA

	HRW Flour	Durum Semolina
Protein (Kjeldahl, 5.7 X N, 14% Moisture Basis)%	10.68	13.30
Moisture	12.10%	12.02%
Ash	0.367%	0.617%
Mixograph		
Absorption %	66	64
Mixing time - minutes	7	4
Tolerance (1=poor, 10=very tolerant)	6	2

When looking at the composition of the pasta formulations, egg increased the protein content of the formulations by approximately 20% (on a 30% moisture basis). There is little difference in protein content whether the equal weight of egg product was there as whole egg, egg yolk, egg white, or reconstituted egg white solids. The formulation containing 65% durum semolina (with whole egg) had 13% more protein than the other egg containing treatments because the durum semolina was higher in protein than the HRW flour. This is better illustrated in Table XI.

Table VIII also shows the ash contents of pasta formulations. The pasta that contained egg yolk was higher in ash content than the non-egg yolk containing formulations. This was probably due to the increased mineral content (Fe, Zn etc.) of egg yolk. In fact the formulation with egg yolk was 76% higher in ash than the no-egg pasta, but the egg white pasta had only 14% more protein. The treatment with 65% durum contained whole egg and had a higher ash (mineral) content than the HRW pasta with whole egg due to durum semolina having a higher ash content than the HRW flour. This is also seen in Table IX.

Discussion

As indicated by the results of the data analysis, pasta containing egg yolk was consistantly less firm than the other formulations. This is probably due to the higher concentration of fat in the egg yolk with roughly 67% of the

TABLE IX

PERCENTAGES OF MOISTURE, PROTEIN*, AND ASH IN HRW PASTA FROM EACH FORMULATION

	Moisture	Protein (14% MB)	Protein (30% MB)	Ash %
No Egg	33.44	10.79	8.56	0.459
Dry Egg White	32.41	12.63	10.21	0.553
Egg Yolk	32.34	12.63	10.20	0.807
Whole Egg	32.82	12.73	10.29	0.596
65% Durum Whole Egg	30.72	14.02	11.62	0.702
Fresh Egg White	30.97	12.63	10.26	0.523

*Kjeldahl, 5.7 X N

solid matter in egg yolk consisting of fat and lipid material (Cook and Briggs, 1986). It is also known that fat has a tenderizing effect in baked goods (Charley, 1982; Campbell et al., 1979; Freeland-Graves and Peckham, 1987; and Baldwin, 1986) and the quantity of fat in the egg yolk pasta may have had a tenderizing effect on the wheat flour. Also, egg yolk contains lecithin (Baldwin 1986). This, too, might affect the texture of the pasta since emulsifiers do have a tenderizing effect on cake and other flour-based baked products (Charley, 1982; and Campbell et al., 1979).

In the case of the egg white pasta, it is also recognized that egg white protein, specifically albumin, coagulates with heat (Charley, 1982; Campbell et al., 1979; Freeland-Graves and Peckham, 1987; and Baldwin, 1986) and may have had a "firming" effect on the pastas that contained whole egg or egg whites.

In comparing and contrasting the durum and the bread wheat flours, differences in texture may not be due to the quantity of protein, or gluten, but rather the quality of the protein. As indicated by Haber et al. (1978), Feillet et al. (1989), Schofield (1983), Dexter and Matsuo (1980) and Pomeranz (1971), protein quality plays an important role in pasta production. However, ignoring the egg yolk treatments (which contain fatty compounds), there appears to be a relationship between increased protein and increased firmness whether the added protein was from whole egg, egg white, or durum. Since durum flour is often higher in protein than HRW (Fabriani and Lintas, 1988) firmness of pasta made from durum may be more a factor of higher total protein than type of protein. This relationship between total protein and pasta firmness should be explored further.

CHAPTER V

CONCLUSIONS AND RECOMMEDATIONS

This study was undertaken to test the effect of different egg products substituted weight for weight for whole egg in pasta made of HRW wheat flour as compared to durum semolina. Texture was measured objectively using the Texturegage equipped with a single blade shear with fresh uncooked, fresh cooked, and dried pastas. The research design was a nested ANOVA with three replications.

Conclusions

1. Texture measurements confirmed previous sensory data that durum did cause an increased firmness in all the pasta treatments (fresh uncooked, fresh cooked or dried) except in the case of the three-cut dried pasta at the eighth week of storage.
2. Texture measurements did detect a difference in firmness due to egg products. The firmest tended to be the egg white pastas. Egg yolk alone, however, seemed to be a tenderizing agent (at least in the levels used in this study) at every stage even in the fresh uncooked pasta dough. The tenderizing effect may be due to fat or lecithin in the yolk, but this was not further explored in this study.

3. The texture measurement procedure used was sensitive enough to detect differences in pasta texture due to treatments.

4. Objective measurements, though convenient and timely, should be supported by subjective evaluations before final product acceptability is determined. Many samples that appeared to have texture ratings within an acceptable range by mechanical measures were judged unacceptable subjectively due to brittleness, fragmentation, poor surface texture, or appearance. This was particularly true of the dried egg white pastas.

5. Results indicate that humidity control is necessary for effective production of a dried pasta product that remains shelf stable without cracking (checking) or fragmenting. Data indicated that after two weeks the quality of the dried pastas deteriorated rapidly with observed checking and fragmentation and lower mean texture ratings. Literature indicates that case hardening during drying can cause this to happen.

Recommendations for Further Research

1. Repeat the dried pasta segment of the study using both heat and humidity controlled equipment.

2. Test the effect of different levels of egg white. The research formula replaced the entire amount of egg with an equal weight of egg white. Would varying weights of egg

white affect pasta texture? Would less egg white contribute to less fragmentation in dried pasta?

3. Test the effect of different levels of egg yolk. The research formula replaced the entire amount of egg with an equal weight of egg yolk. Would less yolk improve the quality of egg yolk pasta? Yolks from 1 1/2 dozen eggs were required to equal the 340g of egg (6 to 7 large eggs) called for in the research formula.
4. Test the effect of different proteins. Would incorporating other proteins, such as casein, soy isolate, or single cell protein, cause an increased firmness similar to that attributed to egg white?

CHAPTER VI

THE EFFECT OF EGG ON THE TEXTURE OF HARD RED WINTER WHEAT PASTA

M. J. ZIMBELMAN, S. K. KNIGHT, W. WARDE, D. DOUGHERTY

INTRODUCTION

The 1980's found Americans seeking a "healthier" way of living. Encouraged by the 1980 Dietary Goals and Guidelines devised by the USDA/USHHS (1980) Americans are limiting the consumption of fats, especially saturated fats, and simple carbohydrates. As a result, pasta (a complex carbohydrate) has gained popularity in the American diet and is served in salads, side dishes, and entrees.

Pasta is usually produced from durum wheat (*Triticum durum*) which grows primarily in the north central states. Durum wheat tends to cost more than the more widely available Hard Red Winter (HRW) bread wheat (*Triticum aestivum*) grown in Oklahoma and other great plains states. Table I shows analytical differences between durum semolina and HRW flours (Fabriani and Lintas, 1988).

Researchers at Oklahoma State University have developed fresh (undried) pasta products using Oklahoma HRW wheat in combination with, and in full replacement of durum semolina. They find no significant difference in the overall sensory quality between the fresh HRW pasta and a similarly prepared durum semolina pasta, although the HRW pasta is rated as paler in color and softer in texture than the durum product (Stokes et al. 1991).

One ingredient often found in pasta is egg, so the effect of egg was explored. The goal of this research was to determining the effect of whole egg and egg products on the texture of hard red winter wheat pasta.

MATERIALS AND METHODS

Pasta Dough Preparation

A single batch of blended varieties of Oklahoma HRW wheat flour, obtained from Shawnee Milling Company, Shawnee, OK, was used throughout this study and was a typical sample of flour milled from Oklahoma HRW wheat. Egg products used for this study included USDA grade A large eggs and pasteurized dried egg white obtained from Deb-El Foods Corporation, Elizabeth, NJ. For this study, the following formula were used:

1. 1360.8g hard red winter (HRW) wheat, 482.2g water.
2. 1360.8g HRW, 340g fresh egg white, water to equal 482.2g total liquid.
3. 1360.8g HRW, 40.4g dried egg white powder, 482.2g water
4. 1360.8g HRW, 340g fresh egg yolk, water to equal 685g total liquid
5. 1360.8g HRW, 340g fresh whole egg, water to equal 585g total liquid

All formula were mixed with enough water to form an extrudable dough. Since the different formulary did not absorb water the same the total liquid was not the same for all formulations. Ingredients were weighed on a Fisher Scientific XT top loading balance and mixed and kneaded in the hopper of a La Parmigiana Model D45 single screw extruding pasta machine for seven minutes. After kneading, the dough was extruded through a shell-shaped die. Random samples of 50 shells from each of the pastas were taken and held in labled, sealed polyethylene bags under refrigeration (2°C) for texture testing of fresh raw and fresh cooked product. An approximate 100g sample of shells from each of the pasta dough formulas was taken immediately after extruding, vacuum sealed, and held in a frozen state for chemical analyses. The entire study was replicated three times.

Preparation of Pasta for Objective Texture Measurements

Raw Pasta Shells

The raw pasta shells were refrigerated (2°C) for approximately 24 hours but received no further treatment before texture analysis.

Boiled Fresh Pasta Shells

The samples of 50 shells from each of the five raw pasta doughs had been sealed in air tight containers, and held refrigerated for approximately 24 hours. The shells from all batches were cooked to the "al dente" stage (two minutes) in boiling water, plunged in cold water, and drained.

Chemical Analysis

Chemical analyses of the five pasta treatments were conducted in the Oklahoma State University Wheat Quality Laboratory using standardized procedures. Moisture content was determined by the modified two stage, air-oven method (AACC Method 44-18). Crude protein was determined by Kjeldahl with boric acid modifications (AACC Method 46-12). Ash (furnace) content was determined using a five-gram sample of approximately 13% initial moisture.

Objective Texture Analysis Procedures

For this research, a Food Technology Corporation TG4C Texturegage equipped with a single blade shear was used. Ten single shells from each formulation were drawn at random from the 50 shell supply. These were placed across the platform of the machine and cut one at a time by the shear blade. The maximum number representing the force in pounds required to break completely through the pasta shell was recorded with a higher number representing a greater firmness.

Statistical Analyses of Texture Data

This experiment followed a Nested Analysis of Variance (ANOVA) design. ANOVA with F tests were run to determine the existence of significant differences; Duncan's Multiple Range (DMR) tests identified those difference. An alpha level of $p \leq 0.05$ was established. (For more details see Appendix C.)

RESULTS

Analytical data on the five uncooked pasta doughs are given in Table II. These pasta data uniformly reflect the characteristics of the flours and egg contents since the figures show Kjeldahl protein increasing as egg and durum are added to the HRW flour. Similarly, ash contents increase with the addition of egg, while moisture content seems to decrease with these additions.

Texture Analyses

Results of Firmness Measures of Fresh Uncooked Pasta Shells

ANOVA showed significant differences among the mean cutting forces of pasta shells from the fresh, uncooked formulations (p= 0.0041). Table III shows the results of the DMR test on 30 separate cuts (10 single cuts, three replications) of pasta shells. The HRW pasta with fresh egg white was significantly firmer than all of the other formulations. The HRW pasta made with egg yolk was significantly softer than all of the other pastas. Between these, in descending order of firmness, were the HRW with no egg, the HRW with dried egg white, and the HRW with whole egg. Differences and similarities between the raw and cooked pastas were: the raw pasta shells tended to require at least three times more force to cut than the cooked shells, and the egg yolk containing pasta was the most tender both before and after cooking.

Firmness Measures of Freshly Cooked Pasta Shells

The mean cutting forces for the freshly cooked pastas are given in Table IV. As seen in this table, the HRW with fresh egg white was significantly firmer than three of the remaining four formulations, but there was no significant difference between it and the HRW with dried egg white. The HRW with egg yolk was significantly less firm than all other formulations.

DISCUSSION

As indicated by the results of the data analysis, pasta containing egg yolk was consistantly less firm than the other formulations. This is probably due to the higher concentration of fat in the egg yolk with roughly 67% of the solid matter in egg yolk consisting of fat and lipid material (Cook and Briggs, 1986). It is also known that fat has a tenderizing effect in baked goods (Charley, 1982;

Campbell et al., 1979; Freeland-Graves and Peckham, 1987; and Baldwin, 1986), and the quantity of fat in the egg yolk pasta may have had a tenderizing effect on the wheat flour. Also, egg yolk contains lecithin (Baldwin, 1986). This, too, might affect the texture of the pasta since emulsifiers do have a tenderizing effect on cake and other flour-based baked products (Charley, 1982; and Campbell et al., 1979).

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CONCLUSIONS

Egg yolk, in the amounts used in this study, consistently caused a decrease in firmness of pasta shells whether raw, or freshly cooked. However, addition of egg whites (either fresh or dried) and whole egg to the HRW flour tended to increase firmness.

REFERENCES

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. Approved Methods of the AACC. Methods 44-18 and 46-12 approved December 1962. The Association. St. Paul. MN.

BALDWIN, R. E. Functional properties of eggs in food. Stadelman, W. J., and Cotterill, O. J., Eds. *Egg Science and Technology*. 1986. The AVI Publishing Company, Inc., Westport, Conn.

CAMPBELL, A. M., PENFIELD, M. P. AND GRISWOLD, R.M. 1979. *The Experimental Study of Food*. Houghton Mifflin Company Boston MS.

CHARLEY, H. 1982. *Food Science* (2nd Ed.). John Wiley & Sons, Inc. New York, New York.

COOK, F., and BRIGGS, G. M. The nutritive value of eggs. Stadelman, W. J., and Cotterill, O. J., Eds. *Egg Science and Technology*. 1986. The AVI Publishing Company, Inc., Westport, Conn.

DEXTER, J.E., and MATSUO, R.R. 1980. Relationship between durum wheat protein properties and pasta dough rheology and spaghetti cooking quality. J. Agric. Food Chem. *28*, 902-904.

FABRIANI, G. and LINTAS, C. Eds. *Durum Chemistry and Technology*. 1988. American Association of Cereal Chemists, Inc., St. Paul. MN.

FEILLET, P., AIT-MOUH, A., KOBREHEL, K., and AUSTRAN, J.C. 1989. The role of low molecular weight glutenin proteins in the determination of cooking quality of pasta products: An overview. Cereal Chem. *66*(1), 26-30.

FREELAND-GRAVES, J. H., and PECKHAM, G. C. 1987. *Foundations of Food Prepration*. Macmillan Publishing Co., Inc. New York, New York.

HABER, T. A., SEYAM, A.A. and BANASIK, O. J. 1978. Functional properties of some high protein products in pasta. J. Agric, Food Chem. *26*(5), 1191-1194.

POMERANZ, Y. 1971. *Wheat Chemistry and Technology*. American Association of Cereal Chemists, Inc., St. Paul, Minnesota.

SCHOFIELD, J. D. 1983. Gluten. Nutrition and Food Science. *82*, 11-13.

STOKES, S. K., KNIGHT, N. S. and WARDE, W. 1991. The quality of pasta made from protein enriched Oklahoma hard red winter wheat. *Proceedings*. SAAS Annual Meeting. Ft Worth.

USDA/USHHS 1980. Nutrition and your health: Dietary guidelines for Americans. U.S. Dept. of Agriculture and U.S. Dept of Health and Human Services. U.S. Government Printing Office. Washington D.C.

TABLE I

WHEAT QUALITY LABORATORY ANALYSIS OF HRW FLOUR AND DURUM SEMOLINA

	HRW Flour	Durum Semolina
Protein (Kjeldahl, 5.7 X N, 14% Moisture Basis)%	10.68	13.30
Moisture	12.10%	12.02%
Ash	0.367%	0.617%
Mixograph		
Absorption %	66	64
Mixing time - minutes	7	4
Tolerance (1=poor, 10=very tolerant)	6	2

TABLE II

PERCENTAGES OF MOISTURE, PROTEIN*, AND ASH IN HRW PASTA FROM EACH FORMULATION

	Moisture	Protein (14% MB)	Protein (30% MB)	Ash %
No Egg	33.44	10.79	8.56	0.459
Dry Egg White	32.41	12.63	10.21	0.553
Egg Yolk	32.34	12.63	10.20	0.807
Whole Egg	32.82	12.73	10.29	0.596
65% Durum Whole Egg	30.72	14.02	11.62	0.702
Fresh Egg White	30.97	12.63	10.26	0.523

*Kjeldahl, 5.7 X N

TABLE III

MEAN SHEAR FORCE RATINGS FOR FRESH UNCOOKED PASTA SHELLS

TREATMENT	SHEAR FORCE (lbs)*
HRW Fresh Egg White	13.4 A
HRW No Egg	9.2 B
HRW Dried Egg White	9.0 B
HRW Whole Egg	7.6 B
HRW Egg Yolk	6.0 B

*As measured by Food Technology Texture System
**Means with the same letter are not significantly different

TABLE IV

MEAN SHEAR FORCE RATINGS FOR FRESH COOKED PASTA SHELLS

TREATMENT	SHEAR FORCE (lbs)*
HRW Fresh Egg White	3.6 A
HRW Dried Egg White	3.2 AB
HRW Whole Egg	2.9 B
HRW No Egg	2.8 B
HRW Egg Yolk	2.1 C

*As measured by Food Technology Texture System

**Means with the same letter are not significantly different

A SELECTED BIBLIOGRAPHY

ADAMS, J. 1987. Pasta puts appeal in lunch. School Food Service Journal. 66-67.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. *Approved Methods of the AACC.* Methods 44-18 and 46-12 approved December 1962. The Association. St. Paul. MN.

ANTOGNELLI, C. 1988. The manufacture and applications of pasta as a food ingredient: A review. J. Fd. Techno. *15*, 125-145.

BALDWIN, R. E. Functional properties of eggs in food. Stadelman, W. J., and Cotterill, O. J., Eds. *Egg Science and Technology*. 1986. The AVI Publishing Company, Inc., Westport, Conn.

BALL, H. R., and GARDNER, F. A. 1968. Physical and functional properties of gamma irradiated liquid egg white. Poultry Sci. *47*(5), 1481-1487.

BALL, H. R. 1987. Functional Properties of chemically modified egg white proteins. JACOS. *64*(12), 1718-1725.

BANASIK, O. J., Dick, J. W. 1982. Extruded products from durum wheat. Cereal Foods World. *27*(11), 553-557.

BOURNE, M. C. 1982. *Food Texture and Viscosity: Concept and Measurement*. Academic Press, Inc. New York, New York.

CAMPBELL, A. M., PENFIELD, M. P. AND GRISWOLD, R.M. 1979. *The Experimental Study of Food*. Houghton Mifflin Company Boston MS.

CHARLEY, H. 1982. *Food Science* (2nd Ed.). John Wiley & Sons, Inc. New York, New York.

COOK, F., and BRIGGS, G. M. The nutritive value of eggs. Stadelman, W. J., and Cotterill, O. J., Eds. *Egg Science and Technology*. 1986. The AVI Publishing Company, Inc., Westport, Conn.

CUMMINGS, D. A., AND OKOS, M. R. 1983. Viscoelastic behavior of extruded durum semolina as a function of temperature and moisture content. Transactions of the ASAE. 1888-1893.

CUMMINGS, G. 1983. How pasta machines perform. Restaurant Business. 212-227.

DEXTER, J.E., and MATSUO, R.R. 1978. The effect of gluten protein fractions on pasta dough rheology and spaghetti making quality. Cereal Chem. *55*(1), 44-57.

DEXTER, J.E., and MATSUO, R.R. 1980. Relationship between durum wheat protein properties and pasta dough rheology and spaghetti cooking quality. J. Agric. Food Chem. *28*, 902-904.

DEXTER, J.E., MATSUO, R.R., and MORGAN, B. C. 1983. Spaghetti stickiness: Some factors influencing stickiness and relationshep to other cooking quality characteristics. J. Food Science. 48, 1545-1551.

DEXTER, J.E., MATSUO, R.R., and MACGREGOR, A.W. 1985. Relationship of instrumental assessment of spaghetti cooking quality to the type and the amount of material rinsed form cooked spaghetti. J. Cereal Science. *3*, 39-53.

FEILLET, P., AIT-MOUH, A., KOBREHEL, K., and AUSTRAN, J.C. 1989. The role of low molecular weight glutenin proteins in the determination of cooking quality of pasta products: An overview. Cereal Chem. *66*(1), 26-30.

FERNANDES, J. L. A., SHUEY, W. C., AND MANEVAL, R. D. 1978. Bread wheat granular millstreams with a potential for pasta production I. Physical and analytic properties. Cereal Chem. *55*(3), 308-320.

FINNEY, P. L., HENRY, S. and JEFFERS, H. 1985. Effect of Wheat Variety, Flour Grinding, and Egg Yolk on Whole Wheat Bread. Cereal Chem. *62*(3), 170-173.

FOOD AND DRUG ADMINISTRATION. 1987. *Code of Federal Regulations*. Office of the Federal Register National Archives and Records Administration. Washington, D.C.

FREELAND-GRAVES, J. H., and PECKHAM, G. C. 1987. *Foundations of Food Preparation*. Macmillan Publishing Co., Inc. New York, New York.

FROST, J., HEGEDUS, E. F., AND GLICKSMAN, M. 1984. Objective characterization of hydrocolloid organoleptic properties. Food Tech. *38*(1), 118-122.

GISSLEN, W. 1983. *Professional Cooking*. John Wiley & Sons, Inc. New York, New York.

HABER, T. A., SEYAM, A.A. and BANASIK, O. J. 1978. Functional properties of some high protein products in pasta. J. Agric, Food Chem. *26*(5), 1191-1194.

HAHN, D. H., Application of rheology in the pasta industry. FARIDI, H., and FAUBION, J. M. Eds. *Dough Rheology and Baked Product Texture*. 1990. Van Nostrand Reinhold, New York, New York.

HEATH, J. L. and OWENS, S. L. 1985. Expansion and Contraction Characteristics of Albumen and Yolk. Poulty Sci *64*, 1098-1105.

JOHNSTON, R. A., QUICK, J. S. and DONNELLY, B. J. 1980. Nohte on comparison of pigment extraction and reflectance colorimeter methods for evaluating semolina color. Cereal Chem. *57*(6), 447-448.

KIM, H. I., SEIB, P. A., POSNER, E., DEYOE, C. W., AND YANG, H. C. 1986. Milling hard red winter wheat to farina: Comparison of cooking quality and color of farina and semolina spaghetti. Cereal Foods World. 31(11), 810-819.

KIM, H. I., SEIB, P. A., POSNER, E., DEYOE, C. W., AND YANG, H. C. 1989. Improving the color and cooking quality of spaghetti from kansas hard winter wheat. Cereal Foods World. *34*(2), 216-223.

KOKINI, J. L. 1985. Fluid and semi-solid food texture and texture-taste interactions. Food Tech. *39*(11) 86-94.

KUSHNIX, U., DU CROS, D. L., LAGUDAH E. and HALLORAN, G. M. 1984. Origin and variation of gliadin proteins associated with pasta quality in durum wheat. Euphytica. *33*, 289-294.

LII, C. Y., and CHANG, S. M. 1981. Characterization of red bean (*Phaseolus radiatus* var. *Aurea*) starch and its noodle quality. J. Food Sc. *46*(1), 78-82.

MA, C. Y., POSTE, L. M., and HOLME, J. 1986. Effects of chemical modifications on the physicochemical and cake-baking properties of egg white. Can. Inst. Food Sci. Technol. J., *19*(1), 17-22.

MAGNUSON, K. M.1985. Uses and functionality of vital wheat gluten. Cereal Foods World. *30*(2), 179-181.

MOLINA M. R., MAYORGA, I., LACHANCE, P. A., and BRESSANI, R. 1975. Production of high-protein quality pasta products using a semolina-corn-soy flour mixture I. Influence of thermal processing of corn flour or pasta quality. Cereal Chem. *52*(2), 240-247.

OH, N. H., SEIB, P. A., WARD, A. B., AND DEYOE, C. W. 1985. Noodles. IV. Influence of flour protein, extraction rate, particle size, and starch damage on the quality characteristics of dry noodles. Cereal Chem. *62*(6), 441-446.

Oklahoma Agricultural Statistics. 1988. Oklahoma Department of Agriculture. Oklahoma City, Oklahoma.

PALVOLGYI, L., SZANIEL, I., and BEKE, B. 1987. Estimates of the pasta quality of durum wheat by diagram method. Cereal Research Communications. *10*(3-4), 197-203.

PELEG, M. 1983. The semantics of rheology and texture. Food Tech. *37*(11), 54-61.

PITSILIS, J. G., BROOKER, D. B., WALTON, H. V. and COTTERILL, O. J. 1984. Rheoligical properties of liquid egg white. Transactions of the ASAE.

POMERANZ, Y. 1971. *Wheat Chemistry and Technology*. American Association of Cereal Chemists, Inc., St. Paul, Minnesota.

PRESTON, K. R., MATSUO, R. R., DEXTER, J. E., TWEED, A. R., KILBORN, R. H., AND TULLY, D. 1986. The suitability of various Canadian wheats for steamed bread and noodle processing for the People's Republic of China. Can. Inst. Food Sci. Technol. J. *19*(3), 114-120.

QUAGLIA, G. B. Other durum wheat products. FABRINI, G. and LINTAS, C. eds. *Durum Chemistry and Tecnology*. 1988. American Association of Cereal Cemists, Inc. St. Paul, Minnesota.

SCHOFIELD, J. D. 1983. Gluten. Nutrition and Food Science. *82*, 11-13.

SHEUY, W. C., WATSON, C. A., MANEVAL, R. D., AND CRAWFORD, R. D. 1977. Comparison of durum semolina and pasta products from various countries. Cereal Foods World. *22*(7), 278-283.

STANLEY, D. W. 1986. Chemical and structural determinants for texture of fabricated foods. Food Tech. *40*(3), 65-68,76.

STOKES, S. K., KNIGHT, N. S. and WARDE, W. 1991. The quality of pasta made from protein enriched Oklahoma hard red winter wheat. *Proceedings*. SAAS Annual Meeting, Ft. Worth.

TONEY, J. and BERGQUIST, D. H. 1983. Functional egg products for the cereal foods industry. Cereal Foods World. *28*(2), 445-447.

TOYOKAWA, H., RUBENTHALER, G. L., POWERS, J. R., and SCHANUS, E. G. 1989. Japanese noodle qualities I. Flour components. Cereal Chem. *66*(5), 382-386.

USDA/USHHS 1980. Nutrition and your health: Dietary guidelines for Americans. U.S. Dept. of Agriculture and U.S. Dept of Health and Human Services. U.S. Government Printing Office. Washington D.C.

APPENDIXES

APPENDIX A

ANALYTICAL DATA

November 28, 1990

Misty Zimbelman
Pasta Samples

	100% AP	AP Dry White	AP Egg Yolk	AP Whole Egg	65/35 No Egg	65/35 Whole Egg
2-Stage Air Oven Moist	33 44	32 41	32 34	32 82	33 46	30 72
Kjeldahl 5 7XN (14% mb)	10 79	12 63	12 63	12 73	12 83	14 02
Kjeldahl 5 7XN (dry basis)	12 23	14 59	14 58	14 70	14 89	16 60
Kjeldahl 5 7XN (30% mb)	8 56	10 21	10 20	10 29	10 42	11 62
Ash %	0 459	0 553	0 807	0 596	0 603	0 702

	Fr Egg White	Durum	Durum Whole Egg
2-Stage Air Oven Moist	30 97	32 52	30 92
Kjeldahl 5 7XN (14% mb)	12 63	13 58	14 76
Kjeldahl 5 7XN (dry basis)	14 66	15 82	17 57
Kjeldahl 5 7XN (30% mb)	10 26	11 07	12 30
Ash %	0 523	0 619	0 739

Kjeldahls were run using 1 gram samples which had been dried to approximately 13 % moisture and ground using the Micro-Hammer Mill A factor of 5 7 was used for Kjeldahl calculations This is standard for wheat products Egg products probably require a different factor (check literature).

Ash was also run on the ground samples which contained approximately 13% moisture The percentage presented here has not been adjusted for moisture content We used 5 gram samples for ash determination

Wheat Quality Laboratory
Oklahoma State University
303 Ag Hall, Agronomy Dept

Doris A Dougherty
405-744-9614

November 16, 1990

Misty Zimbelman
Flour Samples

		All Purpose	Durum	"Typical" Chisholm
Zelany Sedimentation		34 33	12 50	52 00
Sedimentation/protein (as is)		3 14	92	4 60
Kjeldahl 5 7xN (14% mb)		10 68	13 30	11 50
Moisture		12 10	12 02	14 00
Ash%		0 367	0 617	38 - 40
Mixograph	absorption (%)	66	64	65
	mixing time (min)	7 0	4 0	4 5 - 6 00
	Tolerance score (1=poor 10=very tolerant)	6	2	3 - 5

Wheat Quality Laboratory
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303 Ag Hall, Agronomy Dept

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Egg Product Comparison

Quantity	Name	Wgt G	Wtr G	Cal	Prot G	Carb G	Fiber G	F Tot G	F-Sat G	Mono G	Poly G	Chol Mg	A-Car RE	A Pre RE	A-Tot RE	B1 Mg	B2 Mg
100 grm	Egg-large whole-raw	100 0	75 8	142	12 4	1 19	0	9 83	3 25	3 94	1 48	400	0	187	187	0 060	0 490
100 grm	Egg white raw	100 0	88 1	45 2	9 46	1 16	0	0 003	0	0	0	0	0	0	0	0 006	0 266
100 grm	Egg yolk-raw	100 0	48 8	380	16 8	0 241	0	30 8	10 2	12 3	4 64	1253	0	584	584	0 181	0 446

Egg Product Comparison

Quantity	Name	B3 Mg	B6 Mg	B12 Mcg	Fol Mcg	Panto Mg	Vit C Mg	Vit-E Mg	Calc Mg	Cu Mg	Iron Mg	Mg Mg	Phos Mg	Potas Mg	Sel Mcg	Na Mg	Zinc Mg
100 grm	Egg-large whole-raw	0 069	0 146	0 869	44 2	1 16	0	0 819	48 8	0 031	1 67	10 9	185	112	23 8	129	1 17
100 grm	Egg white-raw	0 082	0 003	0 059	15 0	0 226	0	0	11 3	0 037	0 028	8 47	11 3	127	12 5	141	0 169
100 grm	Egg yolk-raw	0 072	0 319	3 90	155	4 54	0	2 57	157	0 211	5 72	18 1	518	90 4	48 0	48 2	3 31

egg white dried

Quantity	Name	Wgt G	Wtr G	Cal	Prot G	Carb G	Fiber G	F-Tot G	F Sat G	Mono G	Poly G	Chol Mg	A-Car RE	A-Pre RE	A-Tot RE	B1 Mg	B2 Mg
11 48 grm	Dried egg white-powder	11 5	0 980	43 1	9 46	0 513	0	0 004	0	0	0	0	0	0	0	0 004	0 266

egg white-dried

Quantity	Name	B3 Mg	B6 Mg	B12 Mcg	Fol Mcg	Panto Mg	Vit C Mg	Vit-E Mg	Calc Mg	Cu Mg	Iron Mg	Mg Mg	Phos Mg	Potas Mg	Sel Mcg	Na Mg	Zinc Mg
11 48 grm	Dried egg white-powder	0 083	0 003	0 061	10 9	0 225	0		10 3		0 028	8 26	10 3	128		142	0 018

The values given for dried egg white powder are what would reconstitute to 100g liquid egg white (based on grams required to yield the same grams of protein as 100g fresh egg white

Data from Food Processor II

Statistical Estimate Values for Nutrient Composition of Eggs Expressed on Shell (per Egg) Liquid/Frozen (per 100 g) and Dehydrated (per 100 g) Bases

	Shell (per egg)[a]			Liquid/frozen (per 100 g)				Dehydrated (per 100 g)			
						Yolk					
Nutrients and units	Whole	White	Yolk	Whole[b]	White[b]	Pure[c]	Commercial[d]	Plain whole[e]	Stab white[f]	Plain yolk[g]	S D[h]
Proximate											
Solids g	13.47	4.6	8.81	24.5	12.1	51.8	44.0	96.8	93.6	97.2	—
Calories	84	19	64	152	50	377	313	600	388	692	4.98
Protein (N × 6.25) g	6.60	3.88	2.74	12.0	10.2	16.1	14.9	47.4	79.1	32.9	0.421
Total lipids g	6.00	—	5.80	10.9	—	34.1	27.5	43.1	—	60.8	0.715
Ash g	0.55	.26	0.29	1.00	0.68	1.69	1.49	4.0	5.3	3.3	0.081
Lipids											
Fatty acids g											
Saturated total	2.01	—	1.95	3.67	—	11.42	9.16	14.51	—	20.35	0.561
8:0	0.027	—	0.027	0.05	—	0.16	0.13	0.20	—	0.29	0.003
10:0	0.082	—	0.080	0.15	—	0.47	0.38	0.59	—	0.84	0.020
12:0	0.027	—	0.026	0.05	—	0.15	0.12	0.20	—	0.27	0.008
14:0	0.022	—	0.022	0.04	—	0.12	0.09	0.16	—	0.20	0.014
16:0	1.37	—	1.31	2.5	—	7.7	6.2	9.84	—	13.8	0.227
18:0	0.462	—	0.459	0.84	—	2.70	2.14	3.36	—	4.73	0.100
20:0	0.022	—	0.022	0.04	—	0.12	0.10	0.16	—	0.22	0.002
Monounsaturated total	2.53	—	2.50	4.60	—	14.67	11.80	18.18	—	25.64	0.411
14:1	0.005	—	0.005	0.01	—	0.03	0.03	0.04	—	0.07	0.002
16:1	0.214	—	0.211	0.39	—	1.24	0.97	1.54	—	2.14	0.047
18:1	2.31	—	2.28	4.2	—	13.4	10.8	16.6	—	23.43	0.352
Polyunsaturated total	0.73	—	0.72	1.32	—	4.20	3.37	5.22	—	7.45	0.133
18:2	0.660	—	0.650	1.20	—	3.82	3.07	4.74	—	6.79	0.216
18:3	0.011	—	0.014	0.02	—	0.08	0.06	0.08	—	0.13	0.020
20:4	0.055	—	0.051	0.10	—	0.30	0.24	0.40	—	0.53	0.029
Cholesterol g	0.264	—	0.258	0.48	—	1.52	1.23	1.90	—	2.72	0.053
Lecithin g	1.27	—	1.22	2.32	—	7.20	5.81	9.16	—	12.84	0.112
Cephalin g	0.253	—	0.241	0.46	—	1.42	1.15	1.82	—	2.54	0.028
Vitamins											
A IU	264	—	260	480	—	1527	1240	1898	—	2740	709
D IU	27	—	27	50	—	161	129	198	—	285	11.6
E mg	0.88	—	0.87	1.6	—	5.1	4.1	6.7	—	9.1	0.837
B_{12} μg	0.48	—	0.48	.88	—	2.83	2.27	3.5	—	5.0	0.616
Biotin μg	11.0	2.58	8.35	20.0	6.8	49.1	40.8	79	53	90	4.55
Choline mg	237	0.46	238	430	1.2	1400	1130	1699	9	2497	172
Folic acid mg	0.023	0.006	0.026	0.060	0.016	0.154	0.128	0.24	0.12	0.28	0.035
Inositol mg	5.94	1.52	4.35	10.8	4.0	25.6	21.4	43	31	47	4.84
Niacin mg	0.045	0.035	0.010	0.082	0.092	0.061	0.067	0.32	0.71	0.15	0.033
Pantothenic acid mg	0.83	0.09	0.73	1.52	0.24	4.3	3.5	6.0	1.9	7.7	0.815
Pyridoxine mg	0.065	0.008	0.057	0.119	0.021	0.334	0.273	0.47	0.16	0.60	0.042
Riboflavin mg	0.18	0.11	0.07	0.33	0.28	0.44	0.41	1.30	2.2	0.91	0.028
Thiamine mg	0.05	0.004	0.048	0.09	0.011	0.28	0.22	0.36	0.09	0.49	0.026
Minerals mg											
Calcium	29.2	3.8	25.2	53	10	148	121	209	78	267	7.88
Chlorine	96.0	66.1	29.9	175	174	176	176	691	1349	389	6.58
Copper	0.033	0.009	0.024	0.061	0.023	0.145	0.121	0.24	0.16	0.27	0.672
Iodine	0.026	0.001	0.024	0.047	0.003	0.141	0.114	0.19	0.02	0.25	34.1
Iron	1.08	0.053	1.02	1.97	0.14	6.0	4.83	7.8	1.09	10.6	0.264
Magnesium	6.33	4.15	2.15	11.5	10.8	12.9	12.5	45	84	27.6	1.19
Manganese	0.021	0.002	0.019	0.038	0.007	0.11	0.09	0.15	0.05	0.19	0.008
Phosphorus	111	8	102	202	22	599	485	798	171	1072	43.6
Potassium	74	57	17	135	150	100	110	533	1163	243	9.28
Sodium	71	63	9	129	165	52	74	510	1279	164	9.88
Sulfur	90	62	28	164	163	165	165	648	1263	366	5.97
Zinc	0.72	0.05	0.66	1.30	0.12	3.89	3.15	5.1	0.93	7.0	0.293
Amino Acids g											
Alanine	0.38	0.24	0.14	0.69	0.64	0.81	0.77	2.73	4.96	1.70	0.061
Arginine	0.42	0.23	0.19	0.77	0.60	1.14	1.03	3.04	4.65	2.28	0.044
Aspartic acid	0.65	0.40	0.25	1.18	1.06	1.44	1.37	4.66	8.22	3.03	0.237
Cystine	0.15	0.11	0.05	0.28	0.28	0.27	0.27	1.11	2.17	0.60	0.024
Glutamic acid	0.85	0.52	0.33	1.54	1.36	1.94	1.83	6.08	10.54	4.04	0.113
Glycine	0.22	0.14	0.08	0.40	0.36	0.49	0.47	1.58	2.79	1.04	0.025
Histidine	0.16	0.09	0.07	0.29	0.24	0.41	0.38	1.15	1.86	0.84	0.017
Isoleucine	0.36	0.21	0.15	0.66	0.56	0.87	0.81	2.61	4.34	1.79	0.069
Leucine	0.57	0.33	0.24	1.04	0.88	1.39	1.29	4.[illegible]	6.82	2.85	0.035
Lysine	0.45	0.25	0.20	0.82	0.66	1.17	1.07	3.24	5.12	2.37	0.046
Methionine	0.21	0.15	0.06	0.39	0.39	0.39	0.39	1.54	3.02	0.86	0.023
Phenylalanine	0.35	0.23	0.12	0.64	0.61	0.69	0.67	2.53	4.73	1.48	0.041
Proline	0.26	0.15	0.11	0.48	0.40	0.65	0.60	1.90	3.10	1.33	0.034
Serine	0.50	0.27	0.23	0.91	0.71	1.36	1.24	3.60	5.50	2.74	0.043
Threonine	0.32	0.18	0.14	0.59	0.47	0.85	0.78	2.33	3.64	1.72	0.036
Tryptophan	0.11	0.07	0.04	0.19	0.17	0.24	0.23	0.75	1.32	0.51	0.014
Tyrosine	0.28	0.16	0.12	0.51	0.41	0.73	0.67	2.02	3.18	1.48	0.023
Valine	0.43	0.27	0.16	0.79	0.72	0.96	0.91	3.12	5.58	2.01	0.080

SOURCE *Cotterill and Glauert (1979)*

[a] Based on 60.9 g shell egg weight with 55.1 g total liquid whole egg, 38.4 g white, and a 16.7 g yolk containing 24.1%, 12.1% and 51.8% solids, respectively (see Cotterill and Geiger 1977)

[b] Based on 24.5% and 12.1% solids, respectively, for whole and white liquid

[c] Pure yolk containing 51.8% solids

[d] Commercial yolk contains 44% egg solids, diluted with egg white only

[e] Produced from whole egg containing 24.5% solids as in Footnote b

[f] Produced from a bacteriologically fermented egg white

[g] Produced from yolk containing 44% solids as in Footnote d

[h] Standard deviation about the regression line for liquid and frozen data

APPENDIX B

STATISTICAL DATA INCLUDING DURUM

```
                                   SAS       8 22 Monday, August 27, 1990

                          Analysis of Variance Procedure
                             Class Level Information

  Class     Levels     Values

  TRT            6     100% AP-DRIED WH 100/ AP-EGG YOLK 100/ AP-FRESH WH
                       100% AP-NO EGG 100/ AP-WHOLE EG DURUM/AP-WHOLE E

  REP            3     1 3 4

                       Number of observations in data set = 180


                                  SAS       8 22 Monday, August 27, 1990  13

                        Analysis of Variance Procedure

Dependent Variable  P1
                                         Sum of           Mean
Source                     DF           Squares         Square    F Value      Pr    F

Model                      17      1259 027778      74 060458      29 75      0 0001

Error                     162       403 200000       2 489506

Corrected Total           179      1662 227778

                     R-Square              C V       Root MSE              P1 Mean

                     0 757388         17 22299       1 577817           9 16111111


Source                     DF         Anova SS    Mean Square    F Value      Pr    F

TRT                         5     915 4277778    183 0855556      73 54      0 0001
REP(TRT)                   12     343 6000000     28 6333333      11 50      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                     DF         Anova SS    Mean Square    F Value      Pr > F

TRT                         5     915 4277778    183 0855556       6 39      0 0041

                                  SAS       8 22 Monday, August 27, 1990  14

                        Analysis of Variance Procedure

Dependent Variable  P3
                                         Sum of           Mean
Source                     DF           Squares         Square    F Value      Pr    F

Model                      17      6102 000000     358 941176      67 08      0 0001

Error                     162       866 800000       5 350617

Corrected Total           179      6968 800000

                     R-Square              C V       Root MSE              P3 Mean

                     0 875617         10 26541       2 313140          22 5333333


Source                     DF         Anova SS    Mean Square    F Value      Pr    F

TRT                         5     4299 600000     859 920000     160 71      0 0001
REP(TRT)                   12     1802 400000     150 200000      28 07      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                     DF         Anova SS    Mean Square    F Value      Pr    F

TRT                         5     4299 600000     859 920000       5 73      0 0063
```

```
                                SAS      8 22 Monday, August 27, 1990  15

                         Analysis of Variance Procedure

Dependent Variable  F1
                                     Sum of            Mean
Source                  DF          Squares          Square   F Value     Pr    F

Model                   17      73 71111111      4 33594771     10 77     0 0001

Error                  162      65 20000000      0 40246914

Corrected Total        179     138 91111111

                  R-Square             C V        Root MSE              F1 Mean

                  0 530635        20 61242        0 634405           3 07777778


Source                  DF        Anova SS    Mean Square    F Value     Pr    F

TPT                      5     57 24444444    11 44888889      28 45     0 0001
REP(TPT)                12     16 46666667     1 37222222       3 41     0 0002

Tests of Hypotheses using the Anova MS for REP(TPT) as an error term

Source                  DF        Anova SS    Mean Square    F Value     Pr > F

TPT                      5     57 24444444    11 44888889       8 34     0 0013




                                SAS      8 22 Monday, August 27, 1990  16

                         Analysis of Variance Procedure

Dependent Variable  F3
                                     Sum of            Mean
Source                  DF          Squares          Square   F Value     Pr    F

Model                   17     586 3111111      34 4888889      37 85     0 0001

Error                  162     147 6000000       0 9111111

Corrected Total        179     733 9111111

                  R-Square             C V        Root MSE              F3 Mean

                  0 798886        12 59632        0 954521           7 57777778


Source                  DF        Anova SS    Mean Square    F Value     Pr    F

TPT                      5     552 3777778    110 4755556     121 25     0 0001
REP(TPT)                12      33 9333333      2 8277778       3 10     0 0006

Tests of Hypotheses using the Anova MS for REP(TPT) as an error term

Source                  DF        Anova SS    Mean Square    F Value     Pr    F

TPT                      5     552 3777778    110 4755556      39 07     0 0001
```

```
                                      SAS      8 __ Monday, August 27, 1990  17

                              Analysis of Variance Procedure

Dependent Variable  D1_2
                                          Sum of            Mean
Source                       DF          Squares          Square   F Value     Pr   F

Model                        17      58 77777778      3 45751634      9 62     0 0001

Error                       162      58 20000000      0 35925926

Corrected Total             179     116 97777778

                       R-Square              C V        Root MSE            D1_2 Mean

                       0 502470         22 10807        0 599382           2 71111111


Source                       DF         Anova SS     Mean Square   F Value     Pr   F

TRT                           5      46 24444444      9 24888889     25 74     0 0001
REP(TRT)                     12      12 50000000      1 04444444      2 91     0 0011

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                       DF         Anova SS     Mean Square   F Value     Pr   F

TRT                           5      46 24444444      9 24888889      8 86     0 0010
```

```
                                      SAS      8 __ Monday, August 27, 1990  18

                              Analysis of Variance Procedure

Dependent Variable  D3_2
                                          Sum of            Mean
Source                       DF          Squares          Square   F Value     Pr   F

Model                        17      413 8277778      24 3428105     28 07     0 0001

Error                       162      140 5000000       0 8672840

Corrected Total             179      554 3277778

                       R-Square              C V        Root MSE            D3_2 Mean

                       0 746540         14 63155        0 931281           6 33888889


Source                       DF         Anova SS     Mean Square   F Value     Pr   F

TRT                           5      359 9611111      71 9922222     83 01     0 0001
REP(TRT)                     12       53 8666667       4 4888889      5 18     0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                       DF         Anova SS     Mean Square   F Value     Pr > F

TRT                           5      359 9611111      71 9922222     16 04     0 0001
```

```
                                            SAS       8 22 Monday, August 27, 1990  19

                                 Analysis of Variance Procedure

Dependent Variable  D1_4
                                         Sum of            Mean
Source                      DF          Squares          Square    F Value       Pr    F

Model                       17      60 29444444      3 54673203      12 30      0 0001

Error                      162      46 70000000      0 28827160

Corrected Total            179     106 99444444

                      R-Square              C V        Root MSE              D1_4 Mean

                      0 563529         22 42313        0 536909             2 39444444


Source                      DF         Anova SS     Mean Square    F Value       Pr    F

TPT                          5      41 36111111      8 27222222      29 11      0 0001
REP(TPT)                    12      18 33333333      1 52777778       5 30      0 0001

Tests of Hypotheses using the Anova MS for REP(TPT) as an error term

Source                      DF         Anova SS     Mean Square    F Value       Pr    F

TPT                          5      41 36111111      8 27222222       5 41      0 0074



                                            SAS       8 22 Monday, August 27, 1990  20

                                 Analysis of Variance Procedure

Dependent Variable  D3_4
                                         Sum of            Mean
Source                      DF          Squares          Square    F Value       Pr    F

Model                       17      318 1777778      18 7163399      21 91      0 0001

Error                      162      138 4000000       0 8543210

Corrected Total            179      456 5777778

                      R-Square              C V        Root MSE              D3_4 Mean

                      0 696875         16 24737        0 924295             5 68888889


Source                      DF         Anova SS     Mean Square    F Value       Pr    F

TPT                          5      293 5777778      58 7155556      68 73      0 0001
REP(TPT)                    12       24 6000000       2 0500000       2 40      0 0070

Tests of Hypotheses using the Anova MS for REP(TPT) as an error term

Source                      DF         Anova SS     Mean Square    F Value       Pr    F

TPT                          5      293 5777778      58 7155556      28 64      0 0001
```

```
                                   SAS      8 22 Monday, August 27, 1990  21

                          Analysis of Variance Procedure

Dependent Variable  D1_6
                                          Sum of             Mean
Source                         DF        Squares           Square    F Value      Pr    F

Model                          17    88 17777778       5 18692810      13 01    0 0001

Error                         162    64 60000000       0 39876543

Corrected Total               179   152 77777778

                         R-Square            C V         Root MSE            D1_6 Mean

                         0 577164       26 43399         0 631479           2 38888889


Source                         DF      Anova SS     Mean Square    F Value      Pr    F

TRT                             5   50 24444444     10 04888889      25 20    0 0001
REP(TRT)                       12   37 93333333      3 16111111       7 93    0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                         DF      Anova SS     Mean Square    F Value      Pr    F

TRT                             5   50 24444444     10 04888889       3 18    0 0467
```

```
                                   SAS      8 22 Monday, August 27, 1990  22

                          Analysis of Variance Procedure

Dependent Variable  D3_6
                                          Sum of             Mean
Source                         DF        Squares           Square    F Value      Pr    F

Model                          17   362 89444444       21 3467320      26 58    0 0001

Error                         162   130 10000000        0 8030864

Corrected Total               179   492 99444444

                         R-Square            C V         Root MSE            D3_6 Mean

                         0 736103       14 94969         0 896151           5 99444444


Source                         DF      Anova SS     Mean Square    F Value      Pr    F

TRT                             5  261 49444444     52 29888889      65 12    0 0001
REP(TRT)                       12  101 40000000      8 45000000      10 52    0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                         DF      Anova SS     Mean Square    F Value      Pr    F

TRT                             5  261 49444444     52 29888889       6 19    0 0046
```

```
                                      SAS       8 22 Monday, August 27, 1990  23

                              Analysis of Variance Procedure

Dependent Variable  D1_8
                                             Sum of            Mean
Source                         DF           Squares          Square    F Value      Pr     F

Model                          17       83 00000000      4 88235294      12 59      0 0001

Error                         162       62 80000000      0 38765432

Corrected Total               179      145 80000000

                         R-Square               C V        Root MSE             D1_8 Mean

                         0 569273          27 07039        0 622619            2 30000000


Source                         DF          Anova SS     Mean Square    F Value      Pr     F

TRT                             5       27 26666667      5 45333333      14 07      0 0001
REP(TRT)                       12       55 73333333      4 64444444      11 98      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                         DF          Anova SS     Mean Square    F Value      Pr     F

TRT                             5       27 26666667      5 45333333       1 17      0 3768
```

```
                                      SAS       8 22 Monday, August 27, 1990  24

                              Analysis of Variance Procedure

Dependent Variable  D3_8
                                             Sum of            Mean
Source                         DF           Squares          Square    F Value      Pr     F

Model                          17       497 8444444      29 2849673      42 89      0 0001

Error                         162       110 6000000       0 6827160

Corrected Total               179       608 4444444

                         R-Square               C V        Root MSE             D3_8 Mean

                         0 818225          14 87279        0 826266            5 55555556


Source                         DF          Anova SS     Mean Square    F Value      Pr     F

TRT                             5       170 8444444      34 1688889      50 05      0 0001
REP(TRT)                       12       327 0000000      27 2500000      39 91      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                         DF          Anova SS     Mean Square    F Value      Pr     F

TRT                             5       170 8444444      34 1688889       1 25      0 3444
```

```
                                          SAS       8 22 Monday, August 27, 1990  25

                               Analysis of Variance Procedure

Dependent Variable  D1_10
                                            Sum of               Mean
Source                          DF          Squares              Square    F Value      Pr > F

Model                           17      69 36111111          4 08006536      11 34      0 0001

Error                          162      58 30000000          0 35987654

Corrected Total                179     127 66111111

                          R-Square              C V            Root MSE              D1_10 Mean

                          0 543322         27 61675            0 599897              2 17222222


Source                          DF         Anova SS         Mean Square    F Value      Pr > F

TRT                              5      25 96111111          5 19222222      14 43      0 0001
REP(TRT)                        12      43 40000000          3 61666667      10 05      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                          DF         Anova SS         Mean Square    F Value      Pr > F

TRT                              5      25 96111111          5 19222222       1 44      0 2807



                                          SAS       8 22 Monday, August 27, 1990  26

                               Analysis of Variance Procedure

Dependent Variable  D3_10
                                            Sum of               Mean
Source                          DF          Squares              Square    F Value      Pr > F

Model                           17      379 2000000          22 3058824      25 30      0 0001

Error                          162      142 8000000          0 8814815

Corrected Total                179      522 0000000

                          R-Square              C V            Root MSE              D3_10 Mean

                          0 726437         17 60386            0 938872              5 33333333


Source                          DF         Anova SS         Mean Square    F Value      Pr > F

TRT                              5      183 6000000          36 7200000      41 66      0 0001
REP(TRT)                        12      195 6000000          16 3000000      18 49      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT) as an error term

Source                          DF         Anova SS         Mean Square    F Value      Pr > F

TRT                              5      183 6000000          36 7200000       2 25      0 1156
```

```
                         SAS       8 22 Monday, August 27, 1990  27

              Analysis of Variance Procedure

        Duncan's Multiple Range Test for variable  P1

NOTE   This test controls the type I comparisonwise error rate, not
       the experimentwise error rate

             Alpha= 0 05  df= 12  MSE= 28 63333

        Number of Means     2      3      4      5      6
        Critical Range  3 005 3 147 3 243 3 293 3 330

Means with the same letter are not significantly different

        Duncan Grouping                Mean       N   TRT

                      A              13 367      30   100/ AP-FRESH WH

                      B               9 767      30   DURUM/AP-WHOLE E
                      B
              C       B               9 233      30   100/ AP-NO EGG
              C       B
              C       B               9 000      30   100/ AP-DRIED WH
              C       B
              C       B               7 600      30   100/ AP-WHOLE EG
              C
              C                       6 000      30   100/ AP-EGG YOLK
```

```
                         SAS       8 22 Monday, August 27, 1990  28

              Analysis of Variance Procedure

        Duncan's Multiple Range Test for variable  P3

NOTE   This test controls the type I comparisonwise error rate, not
       the experimentwise error rate

             Alpha= 0 05  df= 12  MSE= 150 2

        Number of Means     2      3      4      5      6
        Critical Range  6 881 7 203 7 427 7 542 7 626

Means with the same letter are not significantly different

        Duncan Grouping                Mean       N   TRT

                      A              30 833      30   100/ AP-FRESH WH
                      A
              B       A              24 133      30   100/ AP-DRIED WH
              B       A
              B       A              23 700      30   DURUM/AP-WHOLE E
              B
              B                      22 900      30   100/ AP-NO EGG
              B
              B       C              18 400      30   100/ AP-WHOLE EG
                      C
                      C              15 233      30   100/ AP-EGG YOLK
```

```
                              SAS       8 22 Monday, August 27, 1990   29

                   Analysis of Variance Procedure

              Duncan's Multiple Range Test for variable  F1

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                 Alpha= 0 05   df= 12   MSE= 1 372222

              Number of Means      2       3       4       5       6
              Critical Range   0 658   0 689   0 710   0 721   0 729

Means with the same letter are not significantly different

              Duncan Grouping              Mean       N   TRT

                             A            3 833      30   DURUM/AP-WHOLE E
                             A
                             A            3 633      30   100% AP-FRESH WH
                             A
                     B       A            3 200      30   100% AP-DRIED WH
                     B
                     B                    2 867      30   100% AP-WHOLE EG
                     B
                     B                    2 800      30   100% AP-NO EGG

                             C            2 133      30   100% AP-EGG YOLK
```

```
                              SAS       8 22 Monday, August 27, 1990   30

                   Analysis of Variance Procedure

              Duncan's Multiple Range Test for variable  F3

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                 Alpha= 0 05   df= 12   MSE= 2 817778

              Number of Means      2       3       4       5       6
              Critical Range   0 944   0 989   1 019   1 035   1 046

Means with the same letter are not significantly different

              Duncan Grouping              Mean       N   TRT

                             A            9 633      30   DURUM/AP-WHOLE E
                             A
                             A            9 167      30   100% AP-FRESH WH
                             A
                             A            8 833      30   100% AP-DRIED WH

                             B            6 567      30   100% AP-WHOLE EG
                             B
                             B            6 500      30   100% AP-NO EGG

                             C            4 767      30   100% AP-EGG YOLK
```

```
                              SAS       8 22 Monday, August 27, 1990  31

                      Analysis of Variance Procedure

             Duncan's Multiple Range Test for variable  D1_2

NOTE    This test controls the type I comparisonwise error rate, not
        the experimentwise error rate

                 Alpha= 0 05  df= 12  MSE= 1 044444

             Number of Means      2      3      4      5      6
             Critical Range   0 574  0 601  0 613  0 629  0 636

Means with the same letter are not significantly different

             Duncan Grouping                 Mean      N  TRT

                              A             3 400     30  DUFUM/AF-WHOLE E
                              A
                    B         A             3 033     30  100/ AF-FRESH WH
                    B         A
                    B         A    C        2 933     30  100/ AF-WHOLE EG
                    B              C
                    B              C        2 733     30  100/ AP-DRIED WH
                                   C
                              D    C        2 333     30  100/ AF-NO EGG
                              D
                              D             1 833     30  100/ AF-EGG YOLK


                              SAS       8 22 Monday, August 27, 1990  32

                      Analysis of Variance Procedure

             Duncan's Multiple Range Test for variable  D3_2

NOTE    This test controls the type I comparisonwise error rate, not
        the experimentwise error rate

                 Alpha= 0 05  df= 12  MSE= 4 488883

             Number of Means      2      3      4      5      6
             Critical Range   1 190  1 246  1 284  1 304  1 318

Means with the same letter are not significantly different

             Duncan Grouping                 Mean      N  TRT

                              A             7 967     30  DUFUM/AF-WHOLE E
                              A
                    B         A             7 700     30  100/ AP-FRESH WH
                    B         A
                    B         A             6 800     30  100/ AP-DRIED WH
                    B
                    B                       6 533     30  100/ AP-WHOLE EG

                              C             5 067     30  100/ AF-NO EGG
                              C
                              C             3 967     30  100/ AF-EGG YOLK
```

```
                              SAS      8 22 Monday, August 27, 1990  33

                         Analysis of Variance Procedure

                  Duncan's Multiple Range Test for variable  D1_4

NOTE      This test controls the type I comparisonwise error rate, not
          the experimentwise error rate

                        Alpha= 0 05  df= 12  MSE= 1 527778

                   Number of Means     2      3      4      5      6
                   Critical Range   0 694  0 727  0 749  0 761  0 769

Means with the same letter are not significantly different

                   Duncan Grouping            Mean       N   TRT

                                 A            3 067     30   DURUM/AP-WHOLE E
                                 A
                        B        A            2 833     30   100/ AP-FRESH WH
                        B        A
                        B        A    C       2 567     30   100/ AP-DRIED WH
                        B             C
                        B        D    C       2 200     30   100/ AP-WHOLE EG
                                 D    C
                                 D    C       2 067     30   100/ AP-NO EGG
                                 D
                                 D            1 633     30   100/ AP-EGG YOLK
```

```
                              SAS      8 22 Monday, August 27, 1990  34

                         Analysis of Variance Procedure

                  Duncan's Multiple Range Test for variable  D3_4

NOTE      This test controls the type I comparisonwise error rate, not
          the experimentwise error rate

                        Alpha= 0 05  df= 12  MSE= 2 05

                   Number of Means     2      3      4      5      6
                   Critical Range   0 804  0 842  0 868  0 881  0 891

Means with the same letter are not significantly different

                   Duncan Grouping            Mean       N   TRT

                                 A            7 200     30   DURUM/AP-WHOLE E
                                 A
                                 A            6 833     30   100/ AP-FRESH WH
                                 A
                                 A            6 500     30   100/ AP-DRIED WH

                                 B            5 333     30   100/ AP-WHOLE EG
                                 B
                                 B            4 667     30   100/ AP-NO EGG

                                 C            3 600     30   100/ AP-EGG YOLK
```

```
                              SAS      8 22 Monday, August 27, 1990  35

                      Analysis of Variance Procedure

                 Duncan's Multiple Range Test for variable  D1_6

           NOTE  This test controls the type I comparisonwise error rate, not
                 the experimentwise error rate

                         Alpha= 0 05  df= 12  MSE= 0 161111

                  Number of Means      2      3      4      5      6
                  Critical Range   0 998 1 046 1 077 1 094 1 106

           Means with the same letter are not significantly different

                  Duncan Grouping                Mean      N  TRT

                               A                3 000     30  DURUM/AP-WHOLE E
                               A
                               A                2 967     30  100/ AP-FRESH WH
                               A
                               A                2 633     30  100/ AP-DRIED WH
                               A
                      B        A                2 167     30  100/ AP-WHOLE EG
                      B        A
                      B        A                2 033     30  100/ AP-NO EGG
                      B
                      B                         1 533     30  100/ AP-EGG YOLK



                              SAS      8 22 Monday, August 27, 1990  36

                      Analysis of Variance Procedure

                 Duncan's Multiple Range Test for variable  D3_6

           NOTE  This test controls the type I comparisonwise error rate, not
                 the experimentwise error rate

                         Alpha= 0 05  df= 12  MSE= 8 45

                  Number of Means      2      3      4      5      6
                  Critical Range   1 632 1 710 1 762 1 783 1 803

           Means with the same letter are not significantly different

                  Duncan Grouping                Mean      N  TRT

                               A                7 233     30  DURUM/AP-WHOLE E
                               A
                               A                7 200     30  100/ AP-FRESH WH
                               A
                      B        A                6 600     30  100/ AP-DRIED WH
                      B        A
                      B        A                5 867     30  100/ AP-WHOLE EG
                      B
                      B        C                5 267     30  100/ AP-NO EGG
                               C
                               C                3 800     30  100/ AP-EGG YOLK
```

```
                         SAS       8 22 Monday, August 27, 1990  32

                 Analysis of Variance Procedure

         Duncan's Multiple Range Test for variable  D1_8

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                 Alpha= 0 05  df= 12  MSE= 4 644444

          Number of Means      2      3      4      5      6
          Critical Range  1 210 1 268 1 306 1 326 1 341

Means with the same letter are not significantly different

          Duncan Grouping              Mean      N  TRT

                     A                2 700     30  100/ AF-FRESH WH
                     A
                     A                2 700     30  DUFUM/AF-WHOLE E
                     A
                     A                2 500     30  100/ AF-DRIED WH
                     A
                     A                2 333     30  100/ AP-WHOLE EG
                     A
                     A                2 067     30  100/ AP-NO EGG
                     A
                     A                1 600     30  100/ AF-EGG YOLK


                         SAS       8 22 Monday, August 27, 1990  33

                 Analysis of Variance Procedure

         Duncan's Multiple Range Test for variable  D3_8

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                  Alpha= 0 05  df= 12  MSE= 27 25

          Number of Means      2      3      4      5      6
          Critical Range  2 931 3 070 3 164 3 212 3 248

Means with the same letter are not significantly different

          Duncan Grouping              Mean      N  TRT

                     A                6 867     30  100/ AF-DRIED WH
                     A
                     A                6 333     30  DUFUM/AF-WHOLE E
                     A
                     A                5 733     30  100/ AF-FRESH WH
                     A
                     A                5 733     30  100/ AP-WHOLE EG
                     A
                     A                4 733     30  100/ AF-NO EGG
                     A
                     A                3 933     30  100/ AF-EGG YOLK
```

```
                                  SAS       8 22 Monday, August 27, 1990  39

                   Analysis of Variance Procedure

              Duncan's Multiple Range Test for variable  D1_10

         NOTE  This test controls the type I comparisonwise error rate, not
               the experimentwise error rate

                      Alpha= 0 05  df= 12  MSE= 0 616667

               Number of Means      2      3      4      5      6
               Critical Range  1 068 1 119 1 150 1 170 1 183

         Means with the same letter are not significantly different

               Duncan Grouping            Mean      N   TRT

                             A           2 700     30   DUFUM/AP-WHOLE E
                             A
                             A           2 400     30   100/ AP-DRIED WH
                             A
                             A           2 400     30   100/ AP-FRESH WH
                             A
                             A           2 133     30   100/ AP-WHOLE EG
                             A
                             A           1 833     30   100/ AP-NO EGG
                             A
                             A           1 567     30   100/ AP-EGG YOLK
```

```
                                  SAS       8 22 Monday, August 27, 1990  40

                   Analysis of Variance Procedure

              Duncan's Multiple Range Test for variable  D3_10

         NOTE  This test controls the type I comparisonwise error rate, not
               the experimentwise error rate

                      Alpha= 0 05  df= 12  MSE= 16 3

               Number of Means      2      3      4      5      6
               Critical Range  2 267 2 375 2 447 2 484 2 512

         Means with the same letter are not significantly different

               Duncan Grouping            Mean      N   TRT

                             A           6 633     30   DUFUM/AP-WHOLE E
                             A
                             A           6 233     30   100/ AP-DRIED WH
                             A
                     B       A           5 667     30   100/ AP-FRESH WH
                     B       A
                     B       A           5 167     30   100/ AP-WHOLE EG
                     B       A
                     B       A           4 733     30   100/ AP-NO EGG
                     B
                     B                   3 567     30   100/ AP-EGG YOLK
```

```
                                 SAS          [illegible]

                         Analysis of Variance Procedure
                            Class Level Information

   Class      Levels     Values

   TRT           6       100/ AF-DRIED WH 100/ AF-EGG YOLK 100/ AF-FRESH WH
                         100/ AF-NO EGG 100/ AF-WHOLE EG DURUM/AF-WHOLE E

   TIME          5       2 4 6 8 10

   REP           3       1 2 4

                         Number of observations in data set = 300


                                 SAS        3 [illegible] Monday, August 27, 1990

                        Analysis of Variance Procedure

 Dependent Variable  D1
                                          Sum of             Mean
 Source                      DF          Squares            Square    F Value      Pr > F

 Model                       89     388 1600000        4 3613483       12 16      0 0001

 Error                      810     290 6000000        0 3587654

 Corrected Total            839     678 7600000

                       R-Square             C V          Root MSE                D1 Mean

                       0 571866        25 02661          0 598970             2 39333333


 Source                      DF         Anova SS      Mean Square     F Value      Pr > F

 TRT                          5     181 3600000        36 2720000      101 10      0 0001
 TIME                         4      28 5488889         7 1372222       19 89      0 0001
 TRT*TIME                    20      10 3177778         0 5158889        1 44      0 0965
 REP(TRT*TIME)               60     167 9333333         2 7988889        7 80      0 0001

 Tests of Hypotheses using the Anova MS for REP(TRT*TIME) as an error term

 Source                      DF         Anova SS      Mean Square     F Value      Pr > F

 TRT                          5     181 3600000        36 2720000       12 96      0 0001
 TIME                         4      28 5488889         7 1372222        2 55      0 0482
 TRT*TIME                    20      10 3177778         0 5158889        0 18      [illegible]
```

```
                                  SAS       8 [illegible] Monday, August 27, 1990  43

                         Analysis of Variance Procedure

Dependent Variable  D3
                                          Sum of              Mean
Source                         DF         Squares            Square    F Value      Pr > F

Model                          89     2082 915556       23 403546      28 62      0 0001

Error                         810      662 400000        0 817778

Corrected Total               899     2745 315556

                         R-Square            C V         Root MSE               D3 Mean

                         0 758716        15 6395[illegible]        0 904311            5 78222222


 Source                        DF        Anova SS    Mean Square    F Value      Pr > F

TRT                             5    1181 643889     236 328778     288 99      0 0001
TIME                            4     110 971111      27 742778      33 92      0 0001
TRT*TIME                       20      87 928889       4 396444       5 37      0 0001
REP(TRT*TIME)                  60     702 466667      11 707778      14 32      0 0001

Tests of Hypotheses using the Anova MS for REP(TRT*TIME) as an error term

Source                         DF        Anova SS    Mean Square    F Value      Pr > F

TRT                             5    [illegible]3989     236 328778      20 19      0 0001
TIME                            4    [illegible]1     27 [illegible]78       2 37      0 0625
TRT*TIME                 [illegible]    [illegible]     4 [illegible]444    [illegible]    [illegible]


                         SAS       9 [illegible] Monday, August 27, 1990  44

                 Analysis of Variance Procedure

         Duncan's Multiple Range Test for variable  D1

   NOTE  This test controls the type I comparisonwise error rate, not
         the experimentwise error rate

             Alpha= 0 05  df= 60  MSE= 2 798889

         Number of Means      2      3      4      5      6
         Critical Range   0 387  0 407  0 420  0 429  0 437

   Means with the same letter are not significantly different

         Duncan Grouping              Mean      N   TRT

                       A             2 973    150   DURUM/AP-WHOLE E
                       A
                  B    A             2 787    150   100/ AP-FRESH WH
                  B
                  B    C             2 567    150   100/ AP-DRIED WH
                       C
                  D    C             2 333    150   100/ AP-WHOLE EG
                  D
                  D                  2 067    150   100/ AP-NO EGG

                       E             1 633    150   100/ AP-EGG YOLK
```

```
                                SAS       8 22 Monday, August 27, 1990  45

                    Analysis of Variance Procedure

               Duncan's Multiple Range Test for variable  D3

NOTE   This test controls the type I comparisonwise error rate, not
       the experimentwise error rate

                       Alpha= 0 05  df= 60  MSE= 11 70778

               Number of Means     2      3      4      5      6
               Critical Range  0 791  0 832  0 858  0 877  0 893

Means with the same letter are not significantly different

               Duncan Grouping                Mean      N  TRT

                             A               7 073    150  DURUM/AP-WHOLE E
                             A
                             A               6 627    150  100/ AP-FRESH WH
                             A
                             A               6 600    150  100/ AP-DRIED WH

                             B               5 727    150  100/ AP-WHOLE EG

                             C               4 893    150  100/ AP-NO EGG

                             D               3 773    150  100/ AP-EGG YOLK
```

```
                                SAS       8 22 Monday, August 27, 1990  46

                    Analysis of Variance Procedure

               Duncan's Multiple Range Test for variable  D1

NOTE   This test controls the type I comparisonwise error rate, not
       the experimentwise error rate

                       Alpha= 0 05  df= 60  MSE= 2 798889

                  Number of Means     2      3      4      5
                  Critical Range  0 353  0 371  0 383  0 392

Means with the same letter are not significantly different

               Duncan Grouping                Mean      N  TIME

                             A               2 711    180  2
                             A
                        B    A               2 394    180  4
                        B    A
                        B    A               2 389    180  6
                        B
                        B                    2 300    180  8
                        B
                        B                    2 172    180  10
```

```
                                    SAS        8 [illegible] Monday, August [illegible]7, [illegible]

                         Analysis of Variance Procedure

                    Duncan's Multiple Range Test for variable  D3

          NOTE  This test controls the type I comparisonwise error rate, not
                the experimentwise error rate

                            Alpha= 0 05  df= 60  MSE= 11 70778

                       Number of Means     2       3       4       5
                       Critical Range  0 722  0 753  0 784  0 801

          Means with the same letter are not significantly different

                    Duncan Grouping                 Mean      N   TIME

                                  A                 6 333    180   2
                                  A
                         B        A                 5 934    180   6
                         B        A
                         B        A                 5 689    180   4
                         B        A
                         B        A                 5 556    180   8
                         B
                         B                          5 333    180   10


         Level of             Level of          ------------D1---------------
         TRT                  TIME        N         Mean                SD

         100/ AF-DRIED WH      2          30     2 73333333        0 52083046
         100/ AF-DRIED WH      4          30     2 56666667        0 72730204
         100/ AF-DRIED WH      6          30     2 63333333        0 85028731
         100/ AF-DRIED WH      8          30     2 50000000        0 68228824
         100/ AF-DRIED WH      10         30     2 40000000        0 93218320
         100/ AF-EGG YOLK      2          30     1 93333333        0 46113304
         100/ AF-EGG YOLK      4          30     1 63333333        0 49013252
         100/ AF-EGG YOLK      6          30     1 53333333        0 50741626
         100/ AF-EGG YOLK      8          30     1 60000000        0 56324185
         100/ AF-EGG YOLK      10         30     1 56666667        0 50400693
         100/ AF-FRESH WH      2          30     3 03333333        0 66867514
         100/ AF-FRESH WH      4          30     2 83333333        0 69893186
         100/ AF-FRESH WH      6          30     2 96666667        0 76489050
         100/ AF-FRESH WH      8          30     2 70000000        1 17883636
         100/ AF-FRESH WH      10         30     2 40000000        1 06936616
         100/ AF-NO EGG        2          30     2 33333333        0 47946330
         100/ AF-NO EGG        4          30     2 06666667        0 36514837
         100/ AF-NO EGG        6          30     2 03333333        0 55605342
         100/ AF-NO EGG        8          30     2 06666667        0 69149181
         100/ AF-NO EGG        10         30     1 83333333        0 64771925
         100/ AF-WHOLE EG      2          30     2 93333333        0 63968383
         100/ AF-WHOLE EG      4          30     2 20000000        0 66436384
         100/ AF-WHOLE EG      6          30     2 16666667        0 74663998
         100/ AF-WHOLE EG      8          30     2 23333333        0 85835984
         100/ AF-WHOLE EG      10         30     2 13333333        0 62881022
         DURUM/AF-WHOLE E      2          30     3 40000000        0 93218320
```

```
                                  SAS        8 [illegible] Monday, August [illegible], 1990

                      Analysis of Variance Procedure

Level of             Level of            ---------------D1--------------
TRT                  TIME          N         Mean                 SD

DURUM/AP-WHOLE E     4             30      3 06666667          0 63968383
DURUM/AP-WHOLE E     6             30      3 00000000          1 05045146
DURUM/AP-WHOLE E     8             30      2 70000000          0 83666003
DURUM/AP-WHOLE E     10            30      2 70000000          0 65125873

Level of             Level of            ---------------D3--------------
TRT                  TIME          N         Mean                 SD

100/ AP-DRIED WH     2             30      6 80000000          1 21485064
100/ AP-DRIED WH     4             30      6 50000000          1 10640767
100/ AP-DRIED WH     6             30      6 60000000          1 69380209
100/ AP-DRIED WH     8             30      6 86666667          1 67606545
100/ AP-DRIED WH     10            30      6 23333333          1 73569689
100/ AP-EGG YOLK     2             30      3 96666667          0 92785750
100/ AP-EGG YOLK     4             30      3 60000000          0 72397371
100/ AP-EGG YOLK     6             30      3 80000000          0 84690104
100/ AP-EGG YOLK     8             30      3 93333333          0 98026504
100/ AP-EGG YOLK     10            30      3 56666667          0 81720015
100/ AP-FRESH WH     2             30      7 70000000          1 11880478
100/ AP-FRESH WH     4             30      6 93333333          0 87428131
100/ AP-FRESH WH     6             30      7 10000000          1 18612670
100/ AP-FRESH WH     8             30      5 73333333          2 74092022
100/ AP-FRESH WH     10            30      5 66666667          2 20240203
100/ AP-NO EGG       2             30      5 06666667          0 73967996
100/ AP-NO EGG       4       [illegible]   4 [illegible]       0 71115900
100/ AP-NO EGG       6             30      5 26666667          0 94443318
100/ AP-NO EGG       8             30      4 [illegible]       0 73967996
100/ AP-NO EGG       10            30      4 [illegible]       0 78491525
100/ AP-WHOLE EG     2             30      6 [illegible]       1 13664155
100/ AP-WHOLE EG     4             30      5 33333333          0 92226607
100/ AP-WHOLE EG     6             30      5 86666667          0 68144539
100/ AP-WHOLE EG     8             30      5 73333333          1 11210683
100/ AP-WHOLE EG     10            30      5 16666667          0 98552746
DURUM/AP-WHOLE E     2             30      7 96666667          1 12903173
DURUM/AP-WHOLE E     4             30      7 20000000          1 32352716
DURUM/AP-WHOLE E     6             30      7 23333333          1 27801930
DURUM/AP-WHOLE E     8             30      6 33333333          1 42231800
DURUM/AP-WHOLE E     10            30      6 63333333          1 24522075
```

```
                          Analysis of Variance Procedure

Dependent Variable  D1

Tests of Hypotheses using the Anova MS for FEF(TFT*TIME) as an error term

Source                     DF          Anova SS     Mean Square    F Value      Pr > F

TFT                         5      181 3600000      36 2720000      12 36      0 0001
TIME                        4       28 5488889       7 1372222       2 55      0 0482
   TIME                     1       24 7388889      24 7388889       8 84      0 0042
   T                        3        3 8150000       1 2716667       0 46      0 7112
TFT*TIME                   20       10 3177778       0 5158889       0 18      0 9999
   TIME*TFT                 5        3 4194444       0 6838889       0 25      0 9382
   TFT*T                   15        6 8683333       0 4578889       0 16      0 9998
FEF(TPT*TIME)              60      167 9333333       2 7988889       7 80      0 0001
Error                     310      230 6000000       0 3587654

                          Analysis of Variance Procedure

Dependent Variable  D3

Tests of Hypotheses using the Anova MS for FEF(TFT*TIME) as an error term

Source                     DF          Anova SS     Mean Square    F Value      Pr > F

TFT                         5      [illegible]     226 [illegible]78   20 13      0 0001
TIME                        4      110 971111      27 [illegible]778    2 37      0 06[illegible]
   TIME                     1       82 775556      82 775556        7 07      0 010
   T                        3       28 195556       9 398519        0 80      0 4988
TFT*TIME                   20       87 828889       4 391444        0 38      0 9913
   TIME*TFT                 5       54 591111      10 918222        0 93      0 4687
   TFT*T                   15       33 237778       2 215852        0 19      0 9995
FEF(TFT*TIME)              60      702 466667      11 707778       14 32      0 0001
Error                     310      662 400000       0 817778
```

APPENDIX C

STATISTICAL DATA
EXCLUDING DURUM

```
                                        SAS      12 28 Tuesday, April 30, 1991

                              Analysis of Variance Procedure
                                 Class Level Information

          Class       Levels      Values

          EGG            5        DRIED WHITE EGG YOLK FRESH WHITE NO EGG WHOLE EGG

          REF            3        1 3 4

                         Number of observations in data set = 150



                              Analysis of Variance Procedure

       Dependent Variable FAW1
                                               Sum of               Mean
       Source                     DF          Squares             Square     F Value        Pr > F

       Model                      14      1189 360000          84 954286       32 73        0 0001

       Error                     135       350 400000           2 595556

       Corrected Total           149      1539 760000

                            R-Square              C V           Root MSE              FAW1 Mean

                            0 772432          17 2216           1 611073              9 [illegible]4 [illegible]000

       Source                     DF          Anova SS       Mean Square     F Value        Pr > F

       EGG                         4     902 226667        225 556667       86 90        0 0001
       REF EGG                    10     287 133333         28 713333       11 06        0 0001

       Tests of Hypotheses using the Anova MS for REF EGG as an error term

       Source                     DF          Anova SS       Mean Square     F Value        Pr > F

       EGG                         4     902 226667        225 556667        7 86        0 0039


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                              Analysis of Variance Procedure

       Dependent Variable FAW3
                                               Sum of               Mean
       Source                     DF          Squares             Square     F Value        Pr > F

       Model                      14      5293 800000         378 128571       69 39        0 0001

       Error                     135       735 700000           5 449630

       Corrected Total           149      6029 500000

                            R-Square              C V           Root MSE              FAW3 Mean

                            0 877983          10 46826           2 334444              22 300000

       Source                     DF          Anova SS       Mean Square     F Value        Pr > F

       EGG                         4     4250 600000       1062 650000      194 99        0 0001
       REF EGG                    10     1043 200000        104 320000       19 14        0 0001

       Tests of Hypotheses using the Anova MS for REF EGG as an error term

       Source                     DF          Anova SS       Mean Square     F Value        Pr > F

       EGG                         4     4250 600000       1062 650000       10 19        0 0015
```

```
                                        [illegible]                         , 1991   4

                              Analysis of Variance Procedure

Dependent Variable  FFESH1
                                       Sum of            Mean
Source                      DF        Squares           Square    F Value      Pr > F

Model                       14    47 09333333     3 3638095[illegible]       8 55       [illegible]

Error                      105    53 [illegible]        [illegible]

Corrected Total            119   100 1333333[illegible]

                      R-Square           C V          Root MSE          FFESH1 Mean

                      0 470025     31 [illegible]      0 627[illegible]          2 3266667

Source                      DF       Anova SS      Mean Square    F Value      Pr > F

EGG                          4    36 69333333      9 17333333      [illegible]       0 0001
REP(EGG)                    10    10 4[illegible]       1 04[illegible]         2 64       0 0056

Tests of Hypotheses using the Anova MS for REP(EGG) as an error term

Source                      DF       Anova SS      Mean Square    F Value      Pr > F

EGG                          4    36 69333333      9 17333333       8 82       0 0026



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                              Analysis of Variance Procedure

Dependent Variable  FFESH3
                                       Sum of            Mean
Source                      DF        Squares           Square    F Value      Pr > F

Model                       14    433 7000000      30 9809524      32 40       0 0001

Error                      135    129 1000000      0 9562963

Corrected Total            149    562 8000000

                      R-Square           C V          Root MSE          FFESH3 Mean

                      0 77[illegible]25       13 54517       0 9779[illegible]            7 16666667

Source                      DF       Anova SS      Mean Square    F Value      Pr > F

EGG                          4    400 2666667     100 0666667     104 64       0 0001
REP(EGG)                    10     30 4666667       3 0466667       3 50       0 0004

Tests of Hypotheses using the Anova MS for REP(EGG) as an error term

Source                      DF       Anova SS      Mean Square    F Value      Pr > F

EGG                          4    400 2666667     100 0666667      [illegible]       0 0001
```

```
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                               Analysis of Variance Procedure

Dependent Variable: DFYI_1
                                            Sum of             Mean
Source                       DF            Squares           Square   F Value     Pr > F

Model                        14        40.29000000       2.87785714     11.29     0.0001

Error                       135        34.40000000       0.25481481

Corrected Total             149        74.69000000

                       R-Square               C.V.         Root MSE          DFYI_1 Mean

                       0.539450           19.61626         0.504792           2.57333333


Source                       DF           Anova SS      Mean Square   F Value     Pr > F

EGG                           4        29.16000000       7.29000000     28.61     0.0001
REP(EGG)                     10        11.13000000       1.11300000      4.37     0.0001

Tests of Hypotheses using the Anova MS for REP(EGG) as an error term

Source                       DF           Anova SS      Mean Square   F Value     Pr > F

EGG                           4        29.16000000       7.29000000      6.55     0.0074




                                           SAS        12:28 Tuesday, April 30, 1991   7

                               Analysis of Variance Procedure

Dependent Variable: DFYI_3
                                            Sum of             Mean
Source                       DF            Squares           Square   F Value     Pr > F

Model                        14       315.97000000      22.56928571     28.74     0.0001

Error                       135       106.00000000       0.78518519

Corrected Total             149       421.97000000

                       R-Square               C.V.         Root MSE          DFYI_3 Mean

                       0.748797           14.73570         0.886107           6.01333333


Source                       DF           Anova SS      Mean Square   F Value     Pr > F

EGG                           4       264.57000000      66.14250000     84.24     0.0001
REP(EGG)                     10        51.40000000       5.14000000      6.55     0.0001

Tests of Hypotheses using the Anova MS for REP(EGG) as an error term

Source                       DF           Anova SS      Mean Square   F Value     Pr > F

EGG                           4       264.57000000      66.14250000     12.87     0.0006
```

```
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                            Analysis of Variance Procedure

Dependent Variable  DFY4_1
                                        Sum of              Mean
Source                        DF       Squares            Square    F Value      Pr > F

Model                         14    39 96000000       2 85428571       9 91      0 0001

Error                        135    38 90000000       0 28814815

Corrected Total              149    78 86000000

                  R-Square               C V          Root MSE           DFY4_1 Mean

                  0 506721          20 75196          0 536794            2 58[illegible]


Source                        DF       Anova SS      Mean Square    F Value      Pr > F

EGG                            4    25 68000000       6 42000000      22 28      0 0001
FEF(EGG)                      10    14 26666667       1 42666667       4 95      0 0001

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                        DF       Anova SS      Mean Square    F Value      Pr > F

EGG                            4    25 68000000       6 42000000       4 50      0 0244



                                        SAS      12 28 Tuesday, April 30, 1991   3

                            Analysis of Variance Procedure

Dependent Variable  DFY4_3
                                        Sum of              Mean
Source                        DF       Squares            Square    F Value      Pr > F

Model                         14   235 17000000      16 79785714      25 65      0 0001

Error                        135    88 40000000       0 65481481

Corrected Total              149   323 57000000

                  R-Square               C V          Root MSE           DFY4_3 Mean

                  0 726801          15 19169          0 809206            5 32666667


Source                        DF       Anova SS      Mean Square    F Value      Pr > F

EGG                            4   211 36000000      52 84000000      80 70      0 0001
FEF(EGG)                      10    23 81000000       2 38100000       3 63      0 0003

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                        DF       Anova SS      Mean Square    F Value      Pr > F

EGG                            4   211 36000000      52 84000000      22 19      0 0001
```

```
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                        Analysis of Variance Procedure

Dependent Variable  DPY6_1
                                         Sum of            Mean
Source                      DF          Squares          Square   F Value     Pr    F

Model                       14      57 93333333      4 13809524     11 31     0 0001

Error                      135      49 40000000      0 36592593

Corrected Total            149     107 33333333

                      R-Square             C V         Root MSE          DPY6_1 Mean

                      0 539752        26 68756         0 604918           2 26666667


Source                      DF         Anova SS     Mean Square   F Value     Pr    F

EGG                          4      36 80000000      9 20000000     25 14     0 0001
FEF EGG                     10      21 10000000      2 11000000      5 78     0 0001

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                      DF         Anova SS     Mean Square   F Value     Pr    F

EGG                          4      36 80000000      9 20000000      4 36     0 0270



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                        Analysis of Variance Procedure

Dependent Variable  DPY6_3
                                         Sum of            Mean
Source                      DF          Squares          Square   F Value     Pr    F

Model                       14     291 17333333     20 79809524     28 30     [illegible]

Error                      135      99 [illegible]   0 73481481

Corrected Total            149     390 37333333

                      R-Square             C V         Root MSE          DPY6_3 Mean

                      0 745884        14 91671         0 857213           5 74666667


Source                      DF         Anova SS     Mean Square   F Value     Pr    F

EGG                          4     206 24000000     51 56000000     70 17     0 0001
FEF EGG                     10      84 93333333      8 49333333     11 56     0 0001

Tests of Hypotheses using the Anova MS for FEF EGG  as an error term

Source                      DF         Anova SS     Mean Square   F Value     Pr    F

EGG                          4     206 24000000     51 56000000      6 07     0 0096
```

```
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                         Analysis of Variance Procedure

Dependent Variable: DPY8_1
                                       Sum of            Mean
Source                    DF          Squares          Square   F Value     Pr > F

Model                     14      71.04000000      5.07428571     14.07     0.0001

Error                    135      48.70000000      0.36074074

Corrected Total          149     119.74000000

                    R-Square             C.V.        Root MSE         DPY8_1 Mean

                    0.593285          27.5482        0.600617         2.2[illegible]


Source                    DF         Anova SS     Mean Square   F Value     Pr > F

EGG                        4      21.50666667      5.37666667     14.30     0.0001
FEF(EGG)                  10      49.53333333      4.95333333     13.73     0.0001

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                    DF         Anova SS     Mean Square   F Value     Pr > F

EGG                        4      21.50666667      5.37666667      1.03     0.4143



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                         Analysis of Variance Procedure

Dependent Variable: DPY8_3
                                       Sum of            Mean
Source                    DF          Squares          Square   F Value     Pr > F

Model                     14     142.[illegible]     [illegible]     43.56     0.0001

Error                    135     [illegible]     [illegible]

Corrected Total          149     [illegible]

                    R-Square             C.V.        Root MSE         DPY8_3 Mean

                    [illegible]       14.78?48       [illegible]      [illegible]


Source                    DF         Anova SS     Mean Square   F Value     Pr > F

EGG                        4     149.06666667     37.26666667     [illegible].50    0.0001
FEF(EGG)                  10     232.93333333     23.29333333     45.38     0.0001

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                    DF         Anova SS     Mean Square   F Value     Pr > F

EGG                        4     149.06666667     37.26666667      1.27     0.3435
```

```
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                         Analysis of Variance Procedure

Dependent Variable  DFY10_1
                                         Sum of           Mean
Source                       DF          Squares          Square    F Value      Pr > F

Model                        14      57 90000000      4 13563524      11 79      0 0001

Error                       135      47 40000000      0 35111111

Corrected Total             149     105 30000000

                       R-Square            C V        Root MSE         DFY10_1 Mean

                       0 550000      23 27159         0 592546         2 54666667


Source                       DF         Anova SS     Mean Square    F Value      Pr > F

EGG                           4      15 90000000      3 98000000      11 34      0 0001
FEF(EGG)                      1      42 00000000      4 20000000      11 96      0 0001

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                       DF         Anova SS     Mean Square    F Value      Pr > F

EGG                           4      15 90000000      3 98000000       0 95      0 4757


                                  SAS      12 23 Tuesday, April 30, 1991   15

                         Analysis of Variance Procedure

Dependent Variable  DFY1_3
                                         Sum of           Mean
Source                       DF          Squares          Square    F Value      Pr > F

Model                        14     298 89000000     21 3495200       24 57          01

Error                       135     117 30000000      0 8688631

Corrected Total             149     416 19000000

                       R-Square            C V        Root MSE          DFY1_3 Mean

                       0 718160      18 37007          932142          5 07000000


Source                       DF         Anova SS     Mean Square    F Value      Pr > F

EGG                           4     122 76000000     30 69000000      35 32      0 0001
FEF(EGG)                     10     176 10000000     17 61000000      20 27      0 0001

Tests of Hypotheses using the Anova MS for FEF(EGG) as an error term

Source                       DF         Anova SS     Mean Square    F Value      Pr > F

EGG                           4     122 76000000     30 69000000       1 74      0 2170
```

```
                                  SAS      11:23 Tuesday, April [illegible], [illegible]     [illegible]

                      Analysis of Variance Procedure

          Duncan's Multiple Range Test for variable: FAW1

NOTE: This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                   Alpha= 0.05  df= 1[illegible]  MSE= [illegible]8.71000

              Number of Means    2      3      4      5
              Critical Range  3.[illegible]77 3.1[illegible] 3.[illegible]9 3.354

Means with the same letter are not significantly different.

         Duncan Grouping              Mean       N  EGG

                       A             1[illegible].367     30  FRESH WHITE

                       B             9.133     30  NO EGG
                       B
                       B             9.000     30  DRIED WHITE
                       B
                       B             7.500     30  WHOLE EGG
                       B
                       B             6.000     30  EGG YOLK



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                      Analysis of Variance Procedure

          Duncan's Multiple Range Test for variable: FAW2

NOTE: This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                   Alpha= 0.05  df= 1[illegible]  MSE= 1[illegible]

              Number of Means    2      3      4      5
              Critical Range  5.865 6.[illegible] 6.[illegible] 6.[illegible]

Means with the same letter are not significantly different.

         Duncan Grouping              Mean       N  EGG

                       A             30.800     30  FRESH WHITE

                       B             24.133     30  DRIED WHITE
                       B
                       B             22.9[illegible]     30  NO EGG
                       B
                C      B             16.400     30  WHOLE EGG
                C
                C                    15.133     30  EGG YOLK
```

```
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                  Analysis of Variance Procedure

        Duncan's Multiple Range Test for variable  FRESH1

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                  Alpha= 0.05  df= 10  MSE= 1.04

              Number of Means      2        3       4       5
              Critical Range   0.586    0.612   0.62    0.638

Means with the same letter are not significantly different

        Duncan Grouping                 Mean        N   EGG

                        A               3.000       30   FRESH WHITE
                        A
              B         A               3.[illegible]00       30   DRIED WHITE
              B
              B                         2.867       30   WHOLE EGG
              B
              B                         2.800       30   NO EGG

                        C               2.133       30   EGG YOLK



                          SAS        12:26 Tuesday, April 30, 1991   14

                Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable  FRESH2

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                Alpha= 0.05  df= 10  MSE= 2.74267

             Number of Means      2        3       4
              Critical Range   1.51    [illegible]   [illegible]   [illegible]

Means with the same letter are not significantly different

        Duncan Grouping              Mean        N   EGG

                        A            9.[illegible]67       30   FRESH WHITE
                        A
                        A            8.833       30   DRIED WHITE

                        B            6.567       30   WHOLE EGG
                        B
                        B            6.500       30   NO EGG

                        C            4.767       30   EGG YOLK
```

```
                           SAS      12 28 Tuesday, April 30, 1991   2

                  Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable DFY2_

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                Alpha= 0.05  df= 10   MSE= 1.113333

             Number of Means      2      3      4      5
             Critical Range   0.607  0.634  0.650  0.661

Means with the same letter are not significantly different

         Duncan Grouping              Mean      N   EGG

                      A              3.033     30   FRESH WHITE
                      A
             B        A              2.933     30   WHOLE EGG
             B        A
             B        A              2.733     30   DRIED WHITE
             B
             B        C              2.333     30   NO EGG
                      C
                      C              1.933     30   EGG YOLK
```

```
                           SAS      12 28 Tuesday, April 30, 1991   [illegible]

                  Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable DFY2_3

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                Alpha= 0.05  df= 10  MSE= 5.14

             Number of Means      2      3      4      5
             Critical Range   1.302  1.362  1.400  1.413

Means with the same letter are not significantly different

         Duncan Grouping              Mean      N   EGG

                      A              7.700     30   FRESH WHITE
                      A
                      A              6.8[illegible]     30   DRIED WHITE
                      A
                      A              6.333     30   WHOLE EGG

                      B              5.067     30   NO EGG
                      B
                      B              3.367     30   EGG YOLK
```

```
                                    SAS        12:28 Tuesday, April 30, 1991  21

                         Analysis of Variance Procedure

                 Duncan's Multiple Range Test for variable  DRY4_1

            NOTE  This test controls the type I comparisonwise error rate  not
                  the experimentwise error rate

                              Alpha= 0.05  df= 145  MSE= 1.77667

                          Number of Means      2       3       4       5
                          Critical Range   0.680   0.717   0.737   0.748

            Means with the same letter are not significantly different

                      Duncan Grouping               Mean       N  EGG

                                    A              2.800      30  FRESH WHITE
                                    A
                             B      A              2.567      30  DRIED WHITE
                             B      A
                             B      A    C         2.200      30  WHOLE EGG
                             B           C
                             B           C         2.067      30  NO EGG
                                         C
                                         C         1.500      30  EGG YOLK



                                    SAS        12:28 Tuesday, April 30, 1991  22

                         Analysis of Variance Procedure

                 Duncan's Multiple Range Test for variable  DRY4_2

            NOTE  This test controls the type I comparisonwise error rate  not
                  the experimentwise error rate

                              Alpha= 0.05  df= 145  MSE= 2.68

                          Number of Means      2       3       4       5
                          Critical Range   0.836   0.879   0.905   0.926

            Means with the same letter are not significantly different

                      Duncan Grouping               Mean       N  EGG

                                    A              6.800      30  FRESH WHITE
                                    A
                                    A              6.500      30  DRIED WHITE

                                    B              5.300      30  WHOLE EGG
                                    B
                                    B              4.567      30  NO EGG

                                                   3.600      30  EGG YOLK
```

```
                         SAS      12 29 Tuesday, April 30, 1991  24

                Analysis of Variance Procedure

        Duncan's Multiple Range Test for variable DFR6_1

   NOTE  This test controls the type I comparisonwise error rate, not
         the experimentwise error rate

              Alpha= 0 05  df= 10  MSE= 0 211667

            Number of Means      2      3      4      5
            Critical Range   0 838  0 877  0 898  0 91

   Means with the same letter are not significantly different

           Duncan Grouping             Mean      N  EGG

                       A              2 967     30  FRESH WHITE
                       A
              B        A              2 533     30  DRIED WHITE
              B        A
              B        A    C         2 167     30  WHOLE EGG
              B             C
              B             C         2 033     30  NO EGG
                            C
                            C         1 533     30  EGG YOLK


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              Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable DFR6_3

 NOTE  This test controls the type I comparisonwise error rate, not
       the experimentwise error rate

            Alpha= 0 05  df= 10  MSE= 3 493333

          Number of Means      2      3      4      5
          Critical Range   1 674  1 750  1 793  1 824

 Means with the same letter are not significantly different

         Duncan Grouping             Mean      N  EGG

                     A              7 400     30  FRESH WHITE
                     A
            B        A              6 600     30  DRIED WHITE
            B        A
            B        A              5 867     30  WHOLE EGG
            B
            B        C              5 267     30  NO EGG
                     C
                     C              3 900     30  EGG YOLK
```

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                Analysis of Variance Procedure

     Duncan's Multiple Range Test for variable  DRY8_1

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

              Alpha= 0 05  df= 10  MSE= 4 350000

            Number of Means     2      3     4     5
            Critical Range  1 278 1 327 1 374 1 393

Means with the same letter are not significantly different

      Duncan Grouping              Mean       N  EGG

                  A                2 700     30  FRESH WHITE
                  A
                  A                2 500     30  DRIED WHITE
                  A
                  A                2 233     30  WHOLE EGG
                  A
                  A                2 167     30  NO EGG
                  A
                  A                1 600     30  EGG YOLK
```

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                Analysis of Variance Procedure

     Duncan's Multiple Range Test for variable  DRYE_3

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

              Alpha= 0 05  df= 10  MSE= 23 13000

            Number of Means     2      3     4     5
            Critical Range  3 105 3 251 3 342 3 388

Means with the same letter are not significantly different

      Duncan Grouping              Mean       N  EGG

                  A                6 867     30  DRIED WHITE
                  A
                  A                5 733     30  FRESH WHITE
                  A
                  A                5 733     30  WHOLE EGG
                  A
                  A                4 733     30  NO EGG
                  A
                  A                3 933     30  EGG YOLK
```

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               Analysis of Variance Procedure

     Duncan's Multiple Range Test for variable  DFR1_1

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                Alpha= 0 05  df= 10  MSE= 4 2

          Number of Means      2      3      4      5
          Critical Range   1 177  1 231  1 265  1 280

Means with the same letter are not significantly different

       Duncan Grouping               Mean      N  EGG

                     A               2 400     30  DRIED WHITE
                     A
                     A               2 400     30  FRESH WHITE
                     A
                     A               2 100     30  WHOLE EGG
                     A
                     A               1 800     30  NO EGG
                     A
                     A               1 567     30  EGG YOLK



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               Analysis of Variance Procedure

     Duncan's Multiple Range Test for variable  DFR1_3

NOTE  This test controls the type I comparisonwise error rate, not
      the experimentwise error rate

                Alpha= 0 05  df= 10  MSE= 17 61000

          Number of Means      2      3      4      5
          Critical Range   2 411  2 521  2 591  2 627

Means with the same letter are not significantly different

       Duncan Grouping               Mean      N  EGG

                     A               6 200     30  DRIED WHITE
                     A
            B        A               5 667     30  FRESH WHITE
            B        A
            B        A               5 167     30  WHOLE EGG
            B        A
            B        A               4 700     30  NO EGG
            B
            B                        3 567     30  EGG YOLK
```

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VITA

Misty Jean Yates-Zimbelman

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF EGG PRODUCTS ON THE TEXTURE OF PASTA MADE FROM OKLAHOMA HARD RED WINTER WHEAT

Major Field: Food, Nutrition, and Institution Administration

Biographical:

Personal Data: Born in Elk City, Oklahoma, June 23, 1966, the daughter of Jerry C. and Elaine K. (Brown) Yates. Married to Doyle Lynn Zimbelman on May 31, 1985.

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Professional Experience: Student Technician/Biological Aid, USDA-ARS, Stillwater, Oklahoma, 1984 - 1988; Graduate Research Assistant, Oklahoma State University, 1988 - 1990; Dietetic Pre-Professional Experience, St. Mary's Hospital, Enid, Oklahoma/Oklahoma State University, Stillwater, Oklahoma, January, 1989 - December, 1989; Clinical Dietitian, PLD, St. Mary's Hospital, Enid, Oklahoma August 1990

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