SORGHUM GRAIN DRY-MILLING- EXPERIMENTS OF COLD, WARM, HOT CONDITIONING

by

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INTRODUCTION

Grain sorghum is a member of the *Gramineae* family and the tribe *Andropogoneae*. It has many different common names, dependent upon the geographical region; in India, Juar, Jowar; in Sudan, Sudan Dura; in U.S., Milo, milomaize, grain; in China, Kiaoliang; in East Africa, kaffir corn, gyp corn. The *Andropogonae* has four different groups:

(1) Grass sorghum is for roughage use.

(2) Forage or sweet sorghum is for sugar manufacturing.

(3) Broomcorn is for making household sweep brooms.

(4) Grain sorghum is consumed by people as an energy source and is used for animal feed and industrial purposes.

The important tribe which is a close relative to the *Andropogonae* is the *Tripsiceae*, in which corn is the most important species. There are at least 8,000 to 10,000 different types of sorghum which have been collected throughout the world (30). The commercial varieties developed in the U.S. comprise less than 10% of the diverse types available and the one of most important commercial value is *Sorghum Bicolor*.

Sorghum grain is the third most abundant cereal grain in the world, being exceeded only by wheat and rice. About 75% of the world production is consumed by man. In parts of Africa, China, and India, sorghum constitutes more than 70% of the total calories and furnishes much of the proteins in the diet (28).

The distribution of grain sorghum is on all six continents, between latitude 45° North where average summer temperature is more than 20°C and the frost free season is 125 or more days. Unlike rice and wheat, sorghum is so versatile that it can grow well in semi-arid areas of rainfall as low as 15-20 inches annually, and is highly productive in humid areas and under irrigation (14). Not only can the crop endure hot and dry conditions, it is also able to withstand high rainfall, accompanied by some waterlogging of the soil, providing exposure to the latter is not too prolonged.

The United States is the largest grain sorghum producer on earth. In 1975, the U.S. produced 775,534,000 bushels, about one-third of the world production. Asia and Africa grow about 20% of world production (8). Grain sorghum, as a cereal crop in the U.S., is currently exceeded in production only by wheat and corn. There was about 7.5 fold increase in production between 1940 and 1975. In total U.S. acreage, grain sorghum is exceeded by wheat, corn, oats, and barley (21). In 1975, Kansas produced 148,500,000 bushels, about 21% of total U.S. production; the average yield is 56 bu/acre (11). Except for Texas, Kansas is the second largest producer in this continent.

Since the world food demand is large relative to total supply, and the population explosion are major forces in buoying up grain prices. Agreement has been reached between the U.S. and U.S.S.R. on purchase of U.S. corn by Russians for a five year period beginning October 1, 1976. Last year, U.S. sold the Russians 1.4 billion bushels corn, plus exporting to some other regions, reflecting a strong world demand of corn. How to alleviate this situation of pressing demand for corn? The answer is milo because the exportation of sorghum grain is consistently being increased in the past and it can replace corn in many ways. In 1975, U.S. sorghum grain export increased to 250 million bushels. This spectacular advance is very meaningful when one realizes that the U.S. continent is the last region to be immigrated to by the sorghum plant, even though sorghum cultivation is believed to date back about 6,000-7,000 years in eastern Africa. Sorghum products overlap those of corn in both wet and dry milling processes (15). This is because corn and sorghum are close botanical relatives. Chemical analyses indicate that sorghum resembles corn in the proportions of N_2-free extract, protein, and ash (28). Another reason to back up the overpressing demand for corn replaced by grain sorghum is the price discrepancy. The average price for corn is $2.85/Bu in 1975, equivalent to $4.75/cwt, but the average price for sorghum is $4.32/cwt (12). If food markets for sorghum grain are to develop sufficiently in or near major areas of sorghum production and an adequate number of processing firms follow this shift, sorghum's price advantage should then improve significantly the grain's competitive position in those nonfeed markets (28) such as extruder products. Perhaps the best eyewitness would be Deyoe, et al, 1967 who gave an effective description of the accomplishment of grain sorghum relative to corn in Nebraska, which is one of the four major producing sorghum states. The other three are Texas, Kansas, and Oklahoma. He stated, "Corn and sorghum are battling each other for the farmer's land, labor and capital. Corn used to be more profitable to grow than sorghum, but resistance of corn worm to certain chemicals and development of new hybrid sorghum changed the picture."

The U.S. domestic utilization of sorghum grain is generally by the livestock feeding industry, which accounts for 96-98% of the total U.S. annual production. The remaining 2% of domestic disappearance is going to food processing channels. In the past two decades, little research has been carried out to incorporate sorghum into food processing for human consumption. The main shortcoming of grain sorghum as food raw material is due to the poor response to the roller milling system which has been developed for wheat flour production. The pericarp color and the unpleasant odor of grain sorghum itself make the finished products unacceptable to customers. The accurate data on utilization of sorghum grain by wet and dry milling, brewing, breakfast cereals, snack foods manufacturers are hard to procure. The limited number of firms involved precluded publication of the production data, the interchange of a cereal grain and the products in a number of important processing uses, and dual processing of some products, all attribute to incomplete information on sorghum food usage.

Practically, sorghum flour can replace part of the wheat flour in baking formulas for bread, muffins, and cookies. In 1966, Bressari developed "vegetable mixture No. 9, i.e., Incaparina," in which sorghum flour contributed 29%, corn meal 29%, cottonseed flour 38%, torula yeast 3%, calcium carbonate 1%, and vitamins 4500 I.U. In 1967, Gerrish, O. B. developed a well-known cereal mixture, "Freedom Meal," in which sorghum flour contributed 26% of the product, wheat 26%, corn meal 26%, toasted non-fat soy meal 15%, non-fat dried milk 5%, and vitamins with minerals 2%. Sorghum grits can be either roll or extrusion cooked into material having water absorption and viscosity characteristics similar to those of processing corn meal satisfactory for use in corn soy milk (C.S.M.) or be fortified with soy-proteins before cooking. Sorghum germ can be extracted for producing vegetable unsaturated lipids and the defatted germ could be reduced to flour as a nutrient fortifier for bread, due to its 25% of protein with high lysine, which generally is lacking in cereal endosperm (31). The prospect of exporting sorghum flour into foreign markets is also very promising and encouraging. Especially in East Africa, like Uganda, with increased urbanization of the country, local millers are making vigorous attempts to produce larger quantities of sorghum flour commercially. The limitation of the home pestle ground flour will provide a good prosperous future for U.S. sorghum processing plants (25).

The needs for the development of sorghum as a food crop could be rationalized as following:

(1) To get away from the prejudice that it is a coarse grain, in order to maintain the quality of the final products, the allowances of 8% of broken kernels, foreign material, and other grains must be restricted to 2% or below in U.S. No. 2 grade of sorghum. Research has backed up this finding.

(2) To establish the definitions of product quality, and this is the most urgent need to be met.

(3) To concentrate on the improvement of fine quality flour or grits.

(4) To improve methods of handling and storing.

As population pressures required the less fertile and barren land to be brought into cultivation, combined with the new breakthroughs of advanced technology could boost sorghum grain to be a great potential food source in the near future. Sooner or later, sorghum grain will play an inportant role as curbing the presently widening gap between the world food shortage and the skyrocketing population growth rate of underdeveloped countries.

The purpose of the present research, funded by state Government of Kansas project number OR 505, was to investigate the performance of cold, warm, hot conditionings and to select the best conditioning treatment for dry milling of white sorghum grain into acceptable food products. The white sorghum grain bred by "Seed Research Associates, Scott, Kansas" possesses the least odor among the brown, yellow sorghum grain (3).

A method was developed which consisted of impaction milling and different conditioning treatments.

The different products were statistically analyzed for their percent yield and fat, fiber, protein, tannin contents, recoverable oil amount, and agtron color, as reflecting the influence of the different conditioning treatments.

LITERATURE REVIEW

Chemical composition of kernel.

Joseph S. Wall and Charles W. Blessin (1955) (33) stated the composition of sorghum grain is generally similar to those of corn, except sorghum grain has more starch, protein, wax and less oil, pentosan, than corn. Sorghum grain is more variable than that of corn because of the more hazardous and variable conditions of sorghum production. The whole grain contains:

starch	72.0-76.0%
protein	8.0-12.0%
fiber	2.0%
fat	2.7- 3.4%
wax	0.0- 3.0%

The germ itself contains 19 percent protein, 28 percent fat (a good source of oil), and 10 percent ash. The bran has 4.9 percent fat and is composed mostly of cellulose and semi-cellulose. But, appreciable quantities of starch are deposited in the mesocarp tissue of the bran fraction. Kehm (1955) (20) found bran lipid consist mostly of wax, rather than oil, which is similar to carnauba wax and also a good source for the candling industry.

Moisture movement in the kernel.

In 1963, Fan, Chen, and Shellenberger (10) reported that the relationship between the diffusion coefficient of grain sorghum and the absolute temperature still follows the Arrhenius equation as well as corn, wheat does. So the water movement could be interpreted as follows.

During the tempering, the peripheral absorption of water creates stress between wet and dry portions which cause radial and transverse cracks that provide pathways for further penetration of water. These fractures eventually facilitate the formation of grits during milling. Haltmeier (1933) (16) detected the area around the embryo of the wheat absorb water more quickly than any other area of the kernel. Hinton (1955) (17) reported that the water molecules movement, after they permeate thru the pericarp, will be inhibited by the testa layer. To overcome this obstructive effect by the testa layer needs time but it could be facilitated by the application of heat. Campbell and Jones (1955) carried out an experiment to determine the effect of temperature on the rate of penetration of moisture within damp wheat grain. Their findings could be summarized as follows:

(1) The periods required for 85% completion of moisture movement at 20°C, 31.5°C, 43.5°C (68°V, 88.5°F, 111°F) are 24 hrs. 8 hrs., and 2.6 hrs., respectively.

(2) The water movement in Manitoba wheat rate of change of the moisture diffusion coefficient fell off rapidly above 43.5°C (111°F), and level off between 43.5°C and 63°C.

(3) Initial warming of damp wheat to 43.5°C for periods of 1 hr. or more greatly shorten the subsequent period at 20°C required for completion of moisture distribution.

Wheat conditionings.

a. Cold tempering; moisture effect

Jagbir Singh (1973) (27) outlined the role of water in the tempering process. He said, "The water is added in wheat for the following reasons:

(1) Toughen the bran, lest roller mills should pulverize the bran.

(2) In dry wheat, the endosperm is brittle. Water could mellow the endosperm. The more mellow endosperm, the finer the flour and less power consumption.

(3) Middlings are easier to scrape off the bran, gives the bolters more capacity, reduces the work load to purifiers.

(4) To increase the biological activity of wheat as manifested in increasing rate of respiration.

(5) To the mill owner, the moisture is of great economical importance as losses due to refractions are compensated.

Loser (1936) (22) reported that bread baked from flour from the cold tempering is superior to those from warm and hot conditioning wheat. Eustace (1962) (9) found baking tests indicated that flour from the cold soak treatment gave the best loaf of bread. Pelshenke and Schafer (26) studied the effect of moisture level on yields of flour and bran. He found the increase of moisture level resulted in the increase of bran yield, but the decrease of flour yield and power consumption. In 1965, H. Hischke, Jr. (18) found that a decrease in particle size was associated with increase of moisture content in the milling wheat.

b. Cold tempering; time effect

In 1930, McCormick (23) and in 1933, Swanson (29) got two same findings. The first is that the length of tempering does not have much influence on power consumption. The second finding is that the length of tempering had little effect on the amount of middlings released from the break rolls. McCormick also indicated the weight of flour produced showed a trend toward being slightly larger for the longer tempering; but the longer tempering seemed to have no bearing with the flour ash content. Swanson also pointed out excessively long tempering time simply makes the rate of sugar consumption overpass the rate of sugar production and no credit should be proclaimed for this adverse phenomenon. Wichser and Shellenberger (1949) (34) reported no difference in ash, protein content and granulation of flour particles is found when hard red winter wheat was moistened at 16% moisture content and held for 4 hours, 18 hours, and 24 hours.

c. Hot and steam conditioning

The heat of hot and steam conditioning could strengthen the wheat gluten, which is beneficial to the baking quality. They also can reduce the bin space and save tempering time. Heat transfer of a single kernel by steam was more than 10 times faster than for a kernel treated by hot air at 84°C (5). Oversteaming affects the viscosity of pasted flour and this should be avoided. In 1963, Waggle (32) got the findings from his research work. He stated (1) the temperature of steam conditioning caused no significant effect on the percentage of flour yield, (II) as the temperature of steam conditioning increased, the percent of bran yield increased, (III) also the ash content in straight grade flour increased. Schaffer compared the steam conditioning with other normal and hot conditionings. He tested steam conditioning with other normal and hot conditionings. He found the steam conditioning would have higher bran yield, lesser power consumption. He also rationalized the increasing of bran yield; the steam had a hardening effect on the proteineous content of the aleurone layer. The hardening, he postulated, makes it mechanically easier for the flutes of the rolls to scrape the outermost endosperm cells from the bran. Steam conditioning, as well as hot conditioning, has more flexibility than regular tempering methods in switching the wheat mixes. But steam conditioning is hard to control and easy to damage the wheat kernel. The critical temperature drops when the wheat moisture goes up.

Chemical Changes of Cereal Grain Induced by Heat Treatment

There is evidence that heat does alter the properties of protein and starch. Eustace (1962) (9) stated in his Master's thesis that prolonged heating of wheat at 60°C and shortened heating at 70°C and 90°C at a moisture content of 16.5 percent can damage the wheat protein. But he didn't mention the duration of the heating. In 1957, Fox and Foster (13) reported that hot conditioning may cause the denaturation of the wheat protein. In sorghum proteins, the most abundant fraction is the prolamine ranges from 30 to 60 percent of the total crude protein, just like zein protein in corn. To avoid the denaturation of prolamine, Jones and Csonka (19) extracted it at 60°C temperature. As a matter of fact, denaturation of protein is beneficial to the processing sometimes. It improves the protein digestability;

also heat treatment can strengthen the wheat gluten. As long as the temperature of the heat is not so high that not only breaks the peptide bonds, but also destroys the amino acids themselves which will result in a nutritional loss (32). The moderate treatment is good to the processing. Researchers have furnished the information about the critical temperatures which will denature proteins or destroy amino acids. In 1938, Greaves et al. found heating at 100°C (212°F) for 8 hours did not reduce the growth promoting properties of casein and his further studies verified that heating at 120°C (248°F) for 24 hours was less deleterious to the casein than 8 hours at 130°C (266°F). Morgan showed that heat treatment at 140°C for 15 minutes had little depressing effect on the protein index of casein. As far as the destruction of amino acids is concerned, heating at 108°C, for 10 minutes duration, with a moisture range of 13-33 percent, has no apparent destruction of amino acids. Temperature was the main parameter that determined the occurrence of destruction of lysine, arginine, cysteine. Heating to 130°C (266°F) destroyed lysine, but not histidine, and heating to 140°C (284°F) destroyed both, digestability was also lowered. As temperature elevated to 150°C, destruction of those amino acids is evident. The less the moisture content of the material, the less sensitive the proteins to physical and chemical changes (11). Any other effect would be caused by the heat treatment is the gelatinization of starch. Gelatinization of grain sorghum starches is influenced by storage time, climatic conditions and variety (15). The most important parameters of gelatinization are temperature and moisture. The relationship of wheat starch gelatinization between moisture content, time, temperature is shown as follows:

Moisture Content %	Temperature	Time Needed
40	100°F (37.8°C)	7 hours
40	150°F (66°C)	2 hours
40	200°F (93.5°C)	1 hour

If the grain sorghum moisture level is below 40% moisture content, the temperature required for gelatinization will be correspondingly raised. The author clearly knows that the conditioning treatments he used would not cause the amino acid's destruction but might bring about some denaturation of protein and/or partial gelatinization.

Miscellaneous

R. A. Anderson (1969) (2) reported that milling at low moisture will result in slightly higher fat content in the sorghum flour.

MATERIALS AND METHODS

The white sorghum grain was supplied by the "Seed Research Associates," Route 2, Scott City, Kansas 67871. The variety number is 778R. This sorghum hybrid was selected on the basis of its desirable physical characteristics. It has a very thin bran which is easy to be peeled off. The whole kernel is devoid of undesirable pigments. The endosperm has an agreeable yellowish white color which resembles the color of semolina. The brown sorghum, used for comparison of tannin content with that of white grain, is a bird resistant type came from the farm crop of Dr. C. W. Deyoe, 2445 Hobbs Dr., Manhattan, Kansas. The variety number is 615.

This white sorghum grain has:

moisture content	9.3%
protein content	(N x 6.25) 12.8% dB*
fat content	3.4% dB*
fiber content	1.7% dB*

*reported on dry moisture basis.

Experimental conditioning

White sorghum grain was cleaned with the Carter Dockage tester and the Kice aspirator. Sorghum grain was held in fiber drums and was allowed to equilibrate with room atmosphere. The dehull-tempering was done in an open mouth rotating steel drum equipped with a water spray nozzle. Three thousand grams of grain was moistened to 15.5% moisture content and was rotated from 10 to 25 minutes, depending on the humidity of the day. The moment this first tempering was completed, the dehulled grain was conditioned at various temperatures by heating, periods of holding time, and levels of milling moisture. The conditioning treatment was carried out in a Miag Laboratory Conditioner 20133. Regular tap water was added in cold tempering; its temperature was close to room temperature, about 70°F-72°F. Heated air was used in the warm or hot conditioning. Warm and hot conditioning brought the sorghum grain's temperature up to 100°F and 150°F respectively. The different milling moisture levels, holding times, temperatures of the grain are tabulated below:

Initial Moisture Content	Tempering Moisture Content (%)	Grain Temperature (F°)	Holding time (hrs)
9-11.5	17	70°	0.5
	21	110°	1.5
	25	150°	3.5
			8.0

Therefore, there were 3x3x4 = 36 different combinations.

1. 1.5 hrs., 25% M, 110°F
2. 8 hrs., 25% M, 150°F
3. 1.5 hrs., 21% M, 110°F
4. 8 hrs., 21% M, 110°F
5. 3.5 hrs., 21% M, 150°F
6. 0.5 hr., 25% M, 150°F
7. 3.5 hrs., 25% M, 70°F

8. 0.5 hr., 25% M, 110°F
9. 8 hrs., 17% M, 110°F
10. 0.5 hr., 25% M, 70°F
11. 3.5 hrs., 17% M, 150°F
12. 8 hrs., 17% M, 150°F
13. 8 hrs., 25% M, 110°F
14. 0.5 hr., 17% M, 150°F
15. 3.5 hrs., 17% M, 110°F
16. 1.5 hrs., 17% M, 70°F
17. 1.5 hrs., 21% M, 110°F
18. 1.5 hrs., 21% M, 70°F
19. 1.5 hrs., 25% M, 150°F
20. 0.5 hr., 21% M, 150°F
21. 1.5 hrs., 17% M, 150°F
22. 3.5 hrs., 25% M, 110°F
23. 3.5 hrs., 21% M, 110°F
24. 1.5 hrs., 17% M, 110°F
25. 8 hrs., 21% M, 70°F
26. 8 hrs., 25% M, 70°F
27. 0.5 hr., 17% M, 110°F
28. 0.5 hr., 21% M, 110°F
29. 0.5 hr., 21% M, 70°F
30. 8 hrs., 21% M, 150°F
31. 3.5 hrs., 17% M, 70°F
32. 0.5 hr., 17% M, 70°F
33. 8 hrs., 17% M, 70°F

34. 3.5 hrs., 25% M, 150°F
35. 3.5 hrs., 21% M, 70°F
36. 1.5 hrs., 25% M, 70°F

These orders were determined by putting the numbers 1 to 36 inclusive in random order using Snedecor's Table of Randomly Assorted Digits. After the conditioning treatment, the grains were cooled with room air until the grain's temperature equilibrated with room temperature, 72 - 76°F (22 - 23°C). There was 0.5% moisture loss during the cooling, so after having been cooled off, the dehulled sorghum grain would have a 16% moisture content and be ready to mill.

A recording data sheet was used during each conditioning treatment (see page 18).

Experimental milling

The speed of the rotor of the Alpine Kolloplex 160Z pin mill was adjusted to 900 RPM. The rest of the processing is referred on the flow sheet (see page 21).

Chemical analyses of products

There were nine products in each experiment.

1. C. G. coarse grit + 14W (141 μ)
2. M. G. medium grit - 14W + 24LW (869 μ) major products are usually 55% or more
3. F. G. fine grit - 24W + 34W (520 μ)
4. ML meal - 34W + 66W
5. FL flour - 66W

6.	R. D.	red dog - 66W high fat flour
7.	SH	shorts mixture of grit, germ, bran
8.	Gm	germ for feed or oil ext.
9.	Bn	bran for feed or wax ext.

Each product was analyzed for moisture, protein, crude fat and fiber content, which were determined according to the Official Methods of Analysis of the AOAC (4) (11th Ed. 1970). Crude protein was determined by multiplying Kjeldahl nitrogen value by 6.25. All analysis are reported on 14% moisture basis.

Tannin analyses

Tannin content was determined according to the procedures modified by Burns (1971) (12). Only the coarse grit and medium grit were to be determined for tannin content in the consideration of their potential use in the food industry. The tests of No. 27 and No. 39 were checked for comparison between the products of white and brown sorghum grains, Table 79. The procedure of tannin determination is as follows:

Reagents: The reagent is prepared by combining equal volumes of 8% concentrated hydochloric acid (HCl) in methanol and 4% vanillin in methanol (prepare daily). These must be mixed just before use and should not be used after a trace of color appears.

Standard Curve: Prepare a standard curve by adding 100 mg catechin to 50 ml methanol. Use at various dilutions from full strength to 1:10 to construct standard curve. Pipet 2 ml of each dilution into each of two separate tubes. After the 10 dilutions (20 tubes) have been prepared, quickly add 5 ml of

CONDITIONING EXPERIMENT PROCEDURES

DATE: ____________
EXP: ____________
TEST ____________

1. DRUM WARMING UP TEMP ____________ TIME ____________

2. W_1 __________ GM

3. M_1 __________ %

4. X_{1H_2O} _______ C.C. FOR DEBRAN -- WETTING

5. W_2 __________ GM OF DEBRANED KL

6. M_2 __________ % " " "

7. X_{2H_2O} _______ C.C. FOR CONDITIONING ____________________

8a. START HEATING: TIME ____________ TO ___________ W.W/O SIDE HEATING

TEMP

TIME ____

DRUM ____

METER ____

MILO ____

8b. WARING UP DRYING AIR

MAX. VOL. __________ M 3/h= _________ CFM

TEMP. __________, __________ LESS THAN _____DESIRED

9. STOP HEATING: TIME __________ OFF DRUM HEATING

MILO TEMP. __________

M_3 __________

10. START DRYING: TIME __________, TEMP AIR ____________, VOL AIR ______________

	ENTERING AIR	LEAVING AIR
D.B.	__________	__________
W.B.	__________	__________

11\. STOP DRYING: DRYING TIME

CAL. ________ ACT. ________

TIME ________ M_4 ________

12\. COOLING: W_3 ________ WT. OF 16% MC ________

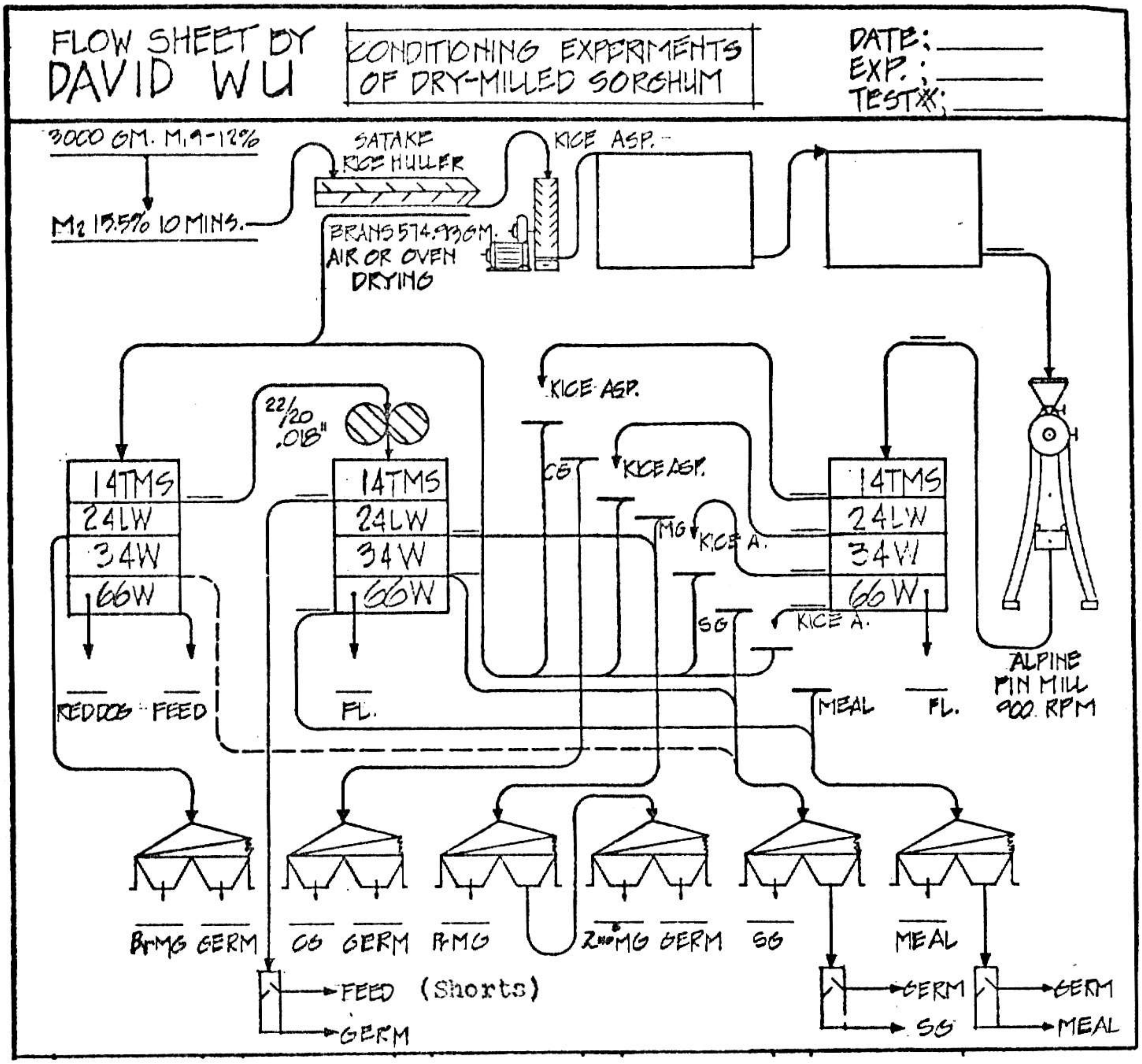
TIME ________ TO ________

MILO TEMP ________ Rm TEMP ________

13\. REWETTING X_{3H_2O} ________ %

THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH DIAGRAMS
THAT ARE CROOKED
COMPARED TO THE
REST OF THE
INFORMATION ON
THE PAGE.

THIS IS AS
RECEIVED FROM
CUSTOMER.


FLOW SHEET BY
DAVID WU
CONDITIONING EXPERIMENTS
OF DRY-MILLED SORGHUM
DATE:
EXP.:
TEST:
3000 GM. M1 9-12%
M2 15.5% 10 MINS.
SATAKE
RICE HULLER
KICE ASP.
BRANS 574.93 GM.
AIR OR OVEN
DRYING
22/20
.018"
14TMS
24LW
34W
66W
14TMS
24LW
34W
66W
KICE ASP.
CG
KICE ASP.
MG
KICE A.
SG
KICE A.
14TMS
24LW
34W
66W
ALPINE
PIN MILL
900 RPM
RED DOG
FEED
FL.
MEAL
FL.
BrMG
GERM
CG
GERM
BrMG
2nd MG
GERM
SG
MEAL
FEED (Shorts)
GERM
GERM
SG
GERM
MEAL

vanillin-HCl reagent to each. Read on colorimeter or spectrophotometer at 500 mμ (525 mμ on some units using filters) after a uniform length of time (20 minutes is satisfactory). The vanillin-HCl is used for the 100% transmittance blank. Plot the transmittance against catechin concentration. See Fig. 1.

Determination: Put 2g ground seed (20-mesh or finer) in 125-ml flask or other suitable container. Add 50 ml of HCl 1% methanol to each flask, opper, swirl. Mix occasionally by swirling. After 7 hours (use the same length of time for all samples) swirl and let settle. Pipet 2 ml of supernatant into each of two tubes and proceed as with standard above.

Extract at one time all samples that are to be compared. This gives relative comparisons without resorting to constant temperature conditions for the extraction and reaction phase. For a rough comparison of cultivars "Ga 615" was used as a standard for high tannin and a change of 1.0% in tannin content was assumed for each 10% change in transmittance. The value for Ga 615 was estimated from previous analyses.

Color measurement

The coarse, medium, fine grits and flour were checked for color reflectance in the blue wavelength using an Agtron color spectrophotometer, Model M-500A. Disc numbers 33 and 68, respectively, were used to get the lower and upper limits of reflectance. The grits were first ground with a hammer mill to pass through a 14 GG (1750μ) screen. A 25 gram sample was thoroughly mixed with 35 ml water. The sample was allowed to rest for 5 minutes. The meter was allowed to stabilize 1-1/2 min. before the reading was taken.

Analysis of Variance

When the measures of percent yield, and fat, protein, fiber, tannin contents and amount of oil, Agtron color are determined. The data will be processed by statistical total analyses of variance, which were performed on an IBM 370/158 using Aardvark. These analyses were supplemented with orthogonal analyses of the main effects: time, moisture, and heat to evaluate the significance of linear, quadratic and (for time) cubic trends. All analyses involving interactions were followed up by means of two-way tables of means and t-tests.

The yield, fat, protein, fiber, tannin color, total oil and Agtron color will be analyzed according to the following outlines:

Source of Variation		Degrees of Freedom
Time		3
Linear trend	1	
Quadratic trend	1	
Cubic trend	1	
Moisture content		2
Linear trend	1	
Quadratic trend	1	
Temperature of Water		2
Linear trend	1	
Quadratic trend	1	
Time x Moisture (Break down as useful)		6
Time x Temperature (Break down as useful)		6
Moisture x Temperature (Break down as useful)		4
Error (Ti x M x Te)		12
Total		35

The coefficients for the orthogonal comparisons in the ANOVA indicated above are as follows:

Time:	0.5 (0)	1.5 (2)	3.5 (6)	8.0 (15)
Linear	-23	-15	+1	+37
Quadratic	+2092	-321	-3023	+1252
(Cubic by substration)				
Moisture:	17 (0)	21 (1)	25 (2)	
Linear	-1	0	+1	
Quadratic	+1	-2	+1	
Temperature:	70° (0)	110° (1)	150° (2)	

Linear	-1	0	+1
Quadratic	+1	-2	+1

The coefficients for break down the Time x Moisture interaction into some possibly useful orthogonal comparisons, each with 1 D F, are given in the following table. Cubic interactions are considered unlikely and ignored.

Time x Moisture

	T_1	T_q	M_1	M_q	T_1M_1	T_1M_q	T_qM_1	T_qM_q
t_0M_0*	-23	+2092	-1	+1	+23	-23	-2092	+2092
t_0M_1	-23	+2092	0	-2	0	+46	0	-4184
t_0M_2	-23	+2092	+1	+1	-23	-23	+2092	+2092
t_2M_0	-15	- 321	-1	+1	+15	-15	+ 321	- 321
t_2M_1	-15	- 321	0	-2	0	+30	0	+ 642
t_2M_2	-15	- 321	+1	+1	-15	-15	- 321	- 321
t_6M_0	+ 1	-3023	-1	+1	- 1	+ 1	+3023	-3023
t_6M_1	+ 1	-3023	0	-2	0	- 2	0	+6046
t_6M_2	+ 1	-3023	+1	+1	+ 1	+ 1	-3023	-3023
$t_{15}M_0$	+37	+1252	-1	+1	-37	+37	-1252	+1252
$t_{15}M_1$	+37	+1252	0	-2	0	-74	0	-2504
$t_{15}M_2$	+37	+1252	+1	+1	+37	+37	+1252	+1252

*This symbol is meant to include all observations with the shortest time, the lowest percent moisture, and all three temperatures at that combination of time and moisture. Similar remarks hold for all other symbols.

The coefficients for breaking down the Time x Temperature interaction similarly are obtained by replacing M by Te in the preceeding table.

The coefficients for breaking down the Moisture x Temperature interaction are the standard ones because the moistures and temperatures are equally spaced.

RESULTS AND DISCUSSION

Table 1. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs 25% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	822	27.00	1.79	14.71	12.66	0.70	32	.174
Medium grit +24LW	1270	42.00	1.31	16.11	13.28	0.60	48.3	.216
Major grit***	2092	61.00	1.47	30.82				
Fine grit +34W	46	1.53	4.91	2.26	14.93	0.77	45.4	
Mean +66LW	43	1.43	6.52	2.80	14.10	1.20		
Flour -66LW	154	5.13	3.21	4.94	10.37	1.35	15	
Premium Product	2335	77.83	1.75	40.82				
Shorts	180	6.00	6.69	12.04	14.36	1.08		
Reddog	34	1.13	11.17	3.80	12.58	4.12		
Germ	111	3.70	16.76	18.60	16.85	3.47		
Bran	311	10.37	8.79	27.34	12.21	7.91		
By-product	536	21.20						
Total yield	2971	99.03						
Loss	29	0.96						
By-product oil recovery %				60.21				
By-product total oil lb/100 cwt				205.85				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit

Table 2. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs	25% MC	150°F	3000 gram sample					
Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	916	30.53	1.26	11.54	12.59	0.68	52.2	.187
Medium grit +24LW	1215	40.50	1.27	15.43	12.48	0.68	41.0	.171
Major grit***	2131	71.03	1.26	26.97				
Fine grit +34W	25	0.83	3.83	0.96	14.82	0.69	39.4	
Meal +66LW	46	1.53	6.37	2.93	15.63	1.35		
Flour -66LW	135	4.50	4.77	6.44	11.29	1.56	11.5	
Premium product	2337	77.90	1.60	37.3				
Shorts	156	5.2	7.08	11.04	15.59	1.15		
Reddog	33	1.10	10.27	3.39	12.37	4.38		
Germ	115	3.83	16.69	19.19	16.13	3.11		
Bran	266	8.87	9.17	24.39	10.57	9.73		
By-product	570	19.00						
Total yield	2907	96.90						
Loss	93	3.10						
By-product oil recovery %				60.86				
By-product total oil lb/100 cwt				193.28				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 3. Yields and Chemical Analyses[*] of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs	21% MC	150°F	3000 gram sample					
Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
Coarse grit +14W	861	28.70	1.08	9.30	12.81	0.69	47.3	.172
Medium grit +24LW	1270	42.33	1.37	17.40	13.01	0.68	53.2	.189
Major grit***	2131	71.03	1.25	26.70				
Fine grit +34W	77	2.57	4.48	3.45	14.78	0.86	39.4	
Meal +66LW	78	2.60	5.94	4.63	14.21	1.07		
Flour -66LW	166	5.53	5.54	9.20	9.69	1.58	24.4	
Premium Product	2452	81.73	1.79	43.98				
Shorts	89	2.97	8.34	7.42	15.44	1.34		
Reddog	44	1.47	10.81	4.76	11.84	4.10		
Germ	144	4.80	16.18	23.30	16.47	3.12		
Bran	258	8.60	9.17	23.66	11.34	9.83		
By-product	535	17.83						
Total yield	2987	99.57						
Loss	13	0.43						
By-product oil recovery %				57.35				
By-product total oil lb/100 cwt				197.05				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 4. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs 21% MC 110°F 3000 gram sample

Fractions	Yield g	%	Crude fat %	Total oil gm	Protein %	Fiber	Color Agtron**	Tannin % of 1 gm sample
Coarse grit +14W	781	26.03	1.16	9.06	12.38	0.68	31	.182
Medium grit +24LW	1284	42.80	1.16	14.89	12.80	0.69	57.9	.158
Major grit***	2065	68.83	1.15	23.95				
Fine grit +34W	87	2.90	6.04	5.25	15.86	1.04	39.5	
Meal +66LW	51	1.70	6.45	3.29	14.98	1.33		
Flour -66LW	176	5.87	7.52	13.24	10.46	1.43	21.9	
Premium product	2379	79.30	1.92	45.73				
Shorts	83	2.77	8.66	7.19	15.41	1.33		
Reddog	37	1.23	11.46	4.24	12.58	4.01		
Germ	141	4.70	16.57	23.36	17.23	2.72		
Bran	266	8.87	8.42	22.40	10.55	9.99		
By-product	527	17.57						
Total yield	2906	96.87						
Loss	94	3.13						
By-product oil recovery %				55.57				
By product total oil lb/100 cwt				190.55				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 5. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs 21% MC 150°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +41W	960	32.00	1.07	16.27	12.03	0.78	51	.146
Medium grit +24LW	1188	39.60	1.55	18.41	12.57	0.68	44.5	.169
Major grit***	2148	71.60	1.34	28.68				
Fine grit +34W	97	3.23	5.95	5.77	15.26	0.86	35.9	
Meal +66LW	86	2.87	6.85	5.89	15.34	1.25		
Flour -66LW	179	5.97	8.16	14.61	10.69	1.26	18.7	
Premium product	2510	83.67	2.18	54.95				
Shorts	92	3.07	9.74	8.96	15.88	1.99		
Reddog	36	1.20	10.18	3.66	12.65	4.09		
Germ	64	2.13	15.98	10.23	15.69	4.54		
Bran	252	8.40	9.31	23.46	10.25	10.63		
By-product	444	14.80						
Total yield	2954	98.47						
Loss	46	1.53						
By-product oil recovery %				45.73				
By-product total oil lb/100 cwt				154.30				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 6. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

0.5 hrs 25% MC 150°F 3000 gram sample

Fractions	Yield g	%	Crude fat %	Total oil gm	Protein %	Fiber %	Color Agtron**	Tannin % of 1 gm sample
Coarse grit +14W	978	32.60	0.86	8.41	12.59	0.68	54.9	.135
Medium grit +24LW	1208	40.27	1.36	16.43	13.13	0.68	52.5	.278
Major grit***	2186	72.87	1.14	24.84				
Fine grit +34W	74	2.49	6.14	4.54	15.34	0.96	39.4	
Meal +66LW	68	2.27	7.68	5.22	14.32	1.23		
Flour -66LW	158	5.27	7.44	11.76	11.06	1.57	15.50	
Premium product	2486	82.87	1.86	46.36				
Shorts	32	1.07	10.67	3.41	15.81	1.24		
Reddog	23	0.77	9.99	2.30	12.65	4.57		
Germ	141	4.70	15.27	21.53	16.30	2.83		
Bran	285	9.50	8.85	25.22	10.82	9.88		
By-product	481	16.03						
Total yield	2967	98.90						
Loss	33	1.10						
By-product oil recovery %				53.09				
By-product total oil lb/100 cwt				174.79				

* On 14% moisture basis including tannin content.

** Discs 33-68

*** Coarse grit + medium grit.

Table 7. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs 25% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	886	29.53	1.18	10.45	12.42	0.69	55	.232
Medium grit +24LW	1290	43.00	1.27	16.38	12.70	0.59	53.4	.171
Major grit***	2176	72.53	1.23	26.83				
Fine grit +34W	85	2.83	4.98	4.23	15.03	0.86	39.2	
Meal +66LW	82	2.73	5.86	4.81	15.38	1.06		
Flour -66LW	150	5.00	5.28	7.92	10.46	1.08	33.4	
Premium product	2493	83.10	1.76	43.79				
Shorts	74	2.47	10.87	8.04	16.17	1.80		
Reddog	35	1.17	10.75	3.76	12.73	3.96		
Germ	128	4.27	16.22	20.76	10.88	3.68		
Bran	256	8.53	8.59	21.99	11.21	10.46		
By-product	493	16.43						
Total yield	2986	99.53						
Loss	14	0.47						
By-product oil recovery %				55.47				
By-product total oil lb/100 cwt				181.76				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 8. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

0.5 hr 25% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	798	26.60	1.09	8.70	12.25	0.79	51.7	.296
Medium grit +24LW	1278	42.60	1.37	17.51	12.71	0.68	51.0	.219
Major grit***	2076	69.20	1.26	26.21				
Fine grit +34W	91	3.03	4.7	4.28	14.88	0.77	43.9	
Meal +66LW	87	2.90	5.78	5.03	14.45	1.06		
Flour -66LW	177	5.90	5.69	10.07	10.40	1.18	19.0	
Premium product	2431	81.03	1.88	45.59				
Shorts	79	2.63	8.58	6.78	15.26	1.62		
Reddog	30	1.00	10.14	3.04	12.40	4.04		
Germ	137	4.57	16.88	23.13	16.41	3.39		
Bran	244	8.13	8.77	21.40	11.41	10.00		
By-product	490	16.33						
Total yield	2921	91.37						
Loss	79	2.63						
By-product oil recovery %				54.38				
By-product total oil lb/100 cwt				181.09				

* On 14% moisture basis including tannin content.

** Discs 33-68

*** Coarse grit + medium grit.

Table 9. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hr 17% MC 110°F 3000 gram sample

Fractions	Yield g	%	Crude fat %	Total oil gm	Pro-tein %	Fiber %	Color Ag-tron**	Tannin % of 1 gm sample
Coarse grit +14W	1082	36.07	0.89	9.63	12.58	0.59	66	.223
Medium grit +24LW	1158	38.60	1.38	15.98	12.95	0.69	60.4	.173
Major grit**	2240	74.67	1.14	25.61				
Fine grit +34W	69	2.30	2.79	1.93	14.81	0.67	53.4	
Meal +66LW	67	2.23	6.64	4.45	14.14	0.87		
Flour -66LW	136	4.53	7.33	9.97	10.60	1.29	38.70	
Premium product	2512	83.73	1.67	41.96				
Shorts	47	1.57	9.74	4.58	16.70	0.72		
Reddog	41	1.37	11.81	4.84	13.05	3.81		
Germ	87	2.90	14.57	12.68	16.37	3.50		
Bran	288	9.60	9.18	26.44	10.95	10.77		
By-product	463	15.43						
Total yield	2975	99.17						
Loss	25	0.83						
By-product oil recovery %				53.64				
By-product total oil lb/100 cwt				161.73				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 10. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hr. 17% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +12W	912	30.40	1.08	9.85	12.21	0.69	56.9	.261
Medium grit +24LW	1363	45.43	1.28	17.45	12.76	0.69	53	.172
Major grit***	2275	75.83	1.20	27.30				
Fine grit +34W	68	2.27	2.76	1.88	14.65	0.67	48.7	
Meal +66LW	82	2.73	6.13	5.03	14.94	1.05		
Flour -66LW	123	4.10	5.96	7.33	10.75	1.07	27	
Premium product	2548	84.93	1.63	41.54				
Shorts	****							
Reddog	42	1.40	11.93	5.01	13.14	4.10		
Germ	124	4.13	15.27	18.93	16.21	2.73		
Bran	286	9.53	10.80	30.89	11.72	9.05		
By-product	452	15.07						
Total yield	3000	100						
By-product oil recovery %				56.90				
By-product total oil lb/100 cwt				182.61				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grits + medium grits.

**** Germ piece intact and large and more germ fraction.

Table 11. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs 17% MC 150°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	994	33.13	1.07	10.64	12.44	0.78	57.0	.146
Medium grit +24LW	1252	41.73	1.47	18.40	12.70	0.68	50.9	.264
Major grit***	2246	74.87	1.28	29.04				
Fine grit +34W	80	2.67	4.72	3.78	14.93	0.67	40.4	
Meal +66LW	72	2.40	6.45	4.64	14.64	1.16		
Flour -66LW	147	4.90	7.70	11.32	10.63	1.37	13.5	
Premium product	2545	84.83	1.92	48.78				
Shorts	19	0.63	9.38	1.78	15.92	1.61		
Reddog	28	0.93	10.69	2.99	12.81	3.95		
Germ	123	4.10	15.98	19.66	16.45	3.40		
Bran	281	9.37	8.97	25.21	11.29	10.13		
By-product	451	15.03						
Total yield	2996	99.86						
Loss	4	0.13						
By-product oil recovery %				47.39				
By-product total oil lb/100 cwt				165.40				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grits + medium grits.

Table 12. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs 17% MC 150°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit -14W	1105	36.83	0.79	8.73	12.70	0.79	48.7	.154
Medium grit +24LW	1097	36.57	1.20	13.16	12.92	0.60	43.6	.138
Major grit***	2202	73.40	0.99	21.89				
Fine grit +34W	70	2.33	4.10	2.87	15.23	0.78	27	
Meal +66LW	72	2.40	6.63	4.77	14.53	1.17		
Flour -66LW	112	3.73	5.90	6.61	10.30	1.20	7	
Premium product	2456	81.87	1.47	36.14				
Shorts	80	2.67	7.53	6.02	15.65	1.84		
Reddog	29	0.97	9.99	2.90	12.51	3.97		
Germ	123	4.1	16.40	20.17	16.40	3.81		
Bran	299	9.97	8.34	24.94	10.99	10.99		
By-product	531	17.70						
Total yield	2987	99.57						
Loss	13	0.43						
By-product oil recovery %				59.92				
By-product total oil lb/100 cwt				180.02				

* On 14% moisture basis including tannin content

** Discs 33-68.

*** Coarse grits + medium grits

Table 13. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs 25% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro- tein	Fiber	Color Ag- tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	1162	38.73	0.79	9.18	12.56	0.59	53	.172
Medium grit +24LW	1017	33.90	1.18	12.00	12.66	0.59	48	.206
Major grit***	2179	72.63	0.97	21.18				
Fine grit +34W	61	2.03	5.18	3.16	14.59	0.67	37.6	
Meal +66LW	80	2.67	5.35	4.28	14.89	0.95		
Flour -66LW	148	4.93	6.18	9.15	11.47	1.30	13.1	
Premium product	2468	82.27	1.53	37.77				
Shorts	89	2.97	10.30	9.17	16.44	1.52		
Reddog	30	1.00	11.69	3.51	13.30	4.62		
Germ	111	3.70	17.81	19.77	16.87	3.96		
Bran	278	9.27	9.69	26.94	10.45	10.82		
By-product	508	16.93						
Total yield	2976	99.20						
Loss	24	0.80						
By-product oil recovery %				61.13				
By-product total oil lb/100 cwt				197.88				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 14. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

0.5 hr 17% MC 150°F 3000 gram sample

Fraction	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	913	30.43	0.80	7.30	12.34	0.70	59.9	.173
Medium grit +24LW	1286	42.87	1.19	15.30	13.25	0.59	56.7	.198
Major grit***	2199	73.30	1.03	22.60				
Fine grit +34W	88	2.93	4.44	3.91	15.15	0.68	40	
Meal +66LW	92	3.07	6.72	6.18	14.70	0.96		
Flour -66LW	148	4.93	7.37	10.91	10.45	1.10	16	
Premium product	2527	84.23	1.73	43.60				
Shorts	53	1.77	11.22	5.95	16.44	1.62		
Reddog	24	0.80	10.66	2.56	12.54	4.90		
Germ	106	3.53	15.94	16.90	15.94	3.87		
Bran	280	9.33	9.71	27.19	11.29	10.27		
By-product	463	15.43						
Total yield	2990	99.67						
Loss	10	0.33						
By-product oil recovery %				54.68				
By-product total oil lb/100 cwt				175.26				

* on 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 15. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs 17% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	865	28.83	1.08	9.34	12.21	0.69	58.7	.185
Medium grit +24LW	1314	43.80	1.38	18.13	13.07	0.69	56	.221
Major grit***	2179	72.63	1.26	27.47				
Fine grit +34W	93	3.10	3.57	3.32	14.94	0.58	49.9	
Meal +66LW	89	2.97	5.89	5.24	14.01	0.97		
Flour -66LW	129	4.30	6.94	8.95	10.17	1.08	38.9	
Premium product	2490	83	1.81	44.98				
Shorts	55	1.83	9.75	5.36	15.96	1.72		
Reddog	38	1.27	12.70	4.83	13.17	4.83		
Germ	83	2.77	14.51	12.04	16.88	3.41		
Bran	323	10.77	10.31	33.30	11.06	9.65		
By-product	499	16.63						
Total yield	2989	99.63						
Loss	11	0.37						
By product oil recovery %				55.25				
By-product total oil lb/100 cwt				185.01				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 16. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs 17% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	1032	34.40	0.50	5.16	12.76	0.70	62.2	.156
Medium grit +24LW	1186	39.53	0.88	9.49	13.01	0.59	59.6	.163
Major grit***	2218	73.93	0.66	14.65				
Fine grit +34W	72	2.40	4.92	3.54	14.94	0.67	49.9	
Meal +66LW	62	2.07	6.56	4.07	14.48	1.06		
Flour -66LW	104	3.47	7.27	7.56	10.57	1.16	26.9	
Premium product	2456	81.87	1.21	29.82				
Shorts	49	1.63	8.25	4.04	16.03	1.63		
Reddog	34	1.13	12.79	4.35	13.45	3.88		
Germ	122	4.07	12.79	15.60	15.65	3.25		
Bran	339	11.3	10.35	35.07	11.95	9.22		
By-product	544	18.13						
Total yield	3000	100						
Loss	0	0						
By-product oil recovery %				66.45				
By-product total oil lb/100 cwt				196.78				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 17. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs 21% MC 110°F 3000 gram sample

Fractions	Yield g	%	Crude fat %	Total oil gm	Protein %	Fiber %	Color Agtron**	Tannin % of 1 gm sample
Coarse grit +14W	931	31.03	0.69	6.42	12.66	0.79	53	.173
Medium grit +24LW	1243	41.43	0.98	12.18	13.07	0.69	44.1	.197
Major grit**	2174	72.47	0.86	18.60				
Fine grit +34W	70	2.33	5.64	3.95	14.35	0.77	40.9	
Meal +66LW	85	2.83	6.43	5.47	14.11	1.34		
Flour -66LW	130	4.33	6.38	8.29	10.06	1.35	30.9	
Premium product	2459	81.97	1.48	36.31				
Shorts	98	3.27	9.86	9.66	15.55	1.80		
Reddog	21	0.70	9.43	1.98	12.14	4.76		
Germ	179	5.97	15.32	27.42	16.46	3.33		
Bran	232	7.73	8.09	18.76	10.57	11.49		
By-product	530	17.67						
Total yield	2989	99.63						
Loss	11	0.37						
By-product oil recovery %				61.43				
By-product total oil lb/100 cwt				192.65				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 18. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

1.5 hrs 21% MC 70°F 3000 gram sample

Fraction	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	882	29.40	0.58	5.12	12.52	0.58	56.1	.158
Medium grit +24LW	1274	42.47	1.06	13.50	12.94	0.68	46	.145
Major grit***	2156	71.87	0.86	18.62				
Fine grit +34W	62	2.07	4.63	2.87	14.63	0.66	37.5	
Meal +66LW	74	2.47	6.49	4.80	15.72	1.32		
Flour -66LW	131	4.37	6.57	8.61	10.57	1.33	18	
Premium product	2423	80.77	1.44	34.90				
Shorts	108	3.60	8.00	8.64	16.28	1.79		
Reddog	39	1.30	10.86	4.24	12.92	4.12		
Germ	129	4.30	16.65	21.48	17.31	3.20		
Bran	257	8.57	18.54	47.65	11.22	10.66		
By-product	533	17.77						
Total Yield	2956	98.52						
Loss	44	1.47						
By-product oil recovery %				70.15				
By-product total oil lb/100 cwt				273.25				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 19. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

1.5 hrs	25% MC		150°F	3000 gram sample				
Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	737	24.57	0.97	7.15	12.44	0.87	48.7	.146
Medium grit +24LW	1357	45.23	1.54	20.90	12.35	0.87	37.4	.236
Major grit***	2094	69.80	1.34	28.05				
Fine grit +34W	94	3.13	5.56	5.23	15.28	0.75	35.9	
Meal +66LW	81	2.70	6.69	5.42	14.13	1.04		
Flour -66LW	158	5.27	6.14	9.70	9.60	1.34	21	
Premium product	2427	80.90	1.99	48.40				
Shorts	65	2.17	10.71	6.96	16.06	1.60		
Reddog	39	1.30	10.73	4.18	12.60	3.45		
Germ	128	4.27	16.49	21.11	16.12	3.19		
Bran	277	9.23	10.39	28.78	12.34	7.52		
By-product	509	16.97						
Total yield	2936	97.87						
Loss	64	2.13						
By-product oil recovery %				55.77				
By-product total oil lb/100 cwt				203.35				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 20. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

0.5 hr 21% MC 150°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	635	21.17	0.87	5.52	12.41	0.78	64.9	.233
Medium grit +24LW	1367	45.57	1.26	17.22	12.76	0.68	61.1	.145
Major grit***	2002	66.73	1.14	22.74				
Fine grit +34W	105	3.50	4.29	4.50	15.07	0.76	40	
Meal +66LW	84	2.80	5.83	4.90	14.73	0.77		
Flour -66LW	164	5.47	5.24	8.59	9.11	1.16	33	
Premium product	2355	78.50	1.73	40.73				
Shorts	68	2.27	8.46	5.75	15.40	1.52		
Reddog	35	1.17	10.90	3.82	12.22	3.69		
Germ	174	5.80	16.47	28.66	16.37	2.84		
Bran	311	10.37	9.96	30.98	11.95	7.59		
By-product	588	19.60						
Total yield	2943	98.10						
Loss	57	1.90						
By-product oil recovery %				62.95				
By-product total oil lb/100 cwt				230.60				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit +medium grit.

Table 21. Yields and Chemical Analyses*of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs 17% MC 150°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	1381	46.03	1.07	14.78	12.58	0.68	61	.123
Medium grit + 24LW	698	23.27	1.08	7.54	12.73	0.59	62.0	.171
Major grit***	2079	69.30	1.07	22.32				
Fine grit +34W	95	3.17	3.18	3.02	14.96	0.68	39.2	
Meal +66LW	73	8.43	6.75	4.93	14.27	0.87		
Flour -66LW	152	5.07	6.59	10.02	9.40	1.34	21.4	
Premium product	2399	79.97	1.68	40.29				
Shorts	85	2.83	13.15	11.18	16.22	1.54		
Reddog	33	1.10	10.94	3.61	12.08	3.40		
Germ	165	5.50	17.50	28.88	17.50	2.28		
Bran	289	9.63	9.15	26.44	11.41	8.11		
By-product	572	19.07						
Total yield	2971	99.03						
Loss	29	0.97						
By-product oil recovery %				63.51				
By-product total oil lb/100 cwt				233.6				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 22. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs	25% MC	110°F	3000 gram sample					
Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	561	18.70	1.04	5.83	12.16	0.47	65	.201
Medium grit +24LW	1319	43.97	1.13	14.90	12.46	0.76	62.8	.135
Major grit***	1880	62.67	1.10	20.73				
Fine grit +34W	94	3.13	3.98	3.74	13.46	0.83	45	
Meal +66LW	76	2.53	4.73	3.59	14.65	1.11		
Flour -66LW	152	5.07	4.39	6.67	9.62	1.21	18.8	
Premium product	2202	73.40	1.58	34.73				
Shorts	66	2.20	7.71	5.09	15.61	1.29		
Reddog	35	1.17	11.15	3.90	12.34	2.95		
Germ	203	6.77	16.86	34.23	16.49	2.58		
Bran	330	11.00	10.01	33.03	11.94	7.25		
By-product	634	21.13						
Total yield	2836	94.53						
Loss	164	5.47						
By-product oil recovery %				68.71				
By-product total oil lb/100 cwt				254.06				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 23. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.'

3.5 hrs 21% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	501	16.70	1.04	5.21	11.98	0.57	61.7	.177
Medium grit + 24LW	1431	47.70	1.22	17.46	12.53	0.75	61	.141
Major grit***	1932	64.40	1.17	22.67				
Fine grit +34W	113	3.77	5.26	5.94	15.03	1.03	40.4	
Meal + 66LW	785	2.62	5.16	4.05	14.92	1.22		
Flour -66LW	175	5.83	5.67	9.92	9.64	1.32	20.4	
Premium product	2298.5	76.62	1.85	42.58				
Shorts	40	1.33	7.89	3.16	15.40	1.39		
Reddog	39	1.30	11.72	4.57	12.18	3.23		
Germ	172	5.73	16.71	28.74	17.08	2.49		
Bran	301	10.03	10.35	31.15	11.82	7.79		
By-product	552	18.40						
Total yield	2850.5	95.02						
Loss	149.5	4.98						
By-product oil recovery %				61.36				
By-product total oil lb/100 cwt				225.30				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 24. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs 17% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	755	25.17	0.96	7.25	11.94	0.58	73.8	.120
Medium grit +24LW	1252	41.73	1.25	15.65	12.38	0.77	68	.163
Major grit***	2007	66.90	1.14	22.90				
Fine grit +34W	95	3.17	5.40	5.13	15.35	0.85	52.5	
Meal +66LW	84	2.80	6.73	5.65	14.97	1.14		
Flour -66LW	146	4.87	7.38	10.77	10.07	1.34	14	
Premium product	2332	77.73	1.91	44.45				
Shorts	90	3.00	8.14	7.33	15.15	1.40		
Reddog	43	1.43	13.12	5.46	12.57	3.70		
Germ	157	5.23	14.60	22.90	16.56	2.60		
Bran	305	10.17	10.47	31.93	11.48	8.26		
By-product	595	19.83						
Total yield	2927	97.57						
Loss	73	2.43						
By-product oil recovery %				60.41				
By-product total oil lb/100 cwt				225.97				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 25. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

8 hrs 21% MC 70°F 3000 gram sample

Fraction	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	532	17.73	1.06	5.64	11.60	0.58	66.5	.169
Medium grit +24LW	1475	49.17	1.56	23.01	12.45	0.58	55.1	.973
Major grit***	2007	66.90	1.43	28.65				
Fine grit +34W	129	4.30	6.20	8.00	16.08	1.65	44.7	
Meal +66LW	87	2.90	5.66	4.92	15.34	0.86		
Flour -66LW	209	6.97	6.98	14.59	10.52	1.47	28.4	
Premium product	2432	81.07	2.31	56.16				
Shorts	61.5	2.05	9.56	5.88	16.15	1.43		
Reddog	26	0.87	11.60	3.02	12.55	3.80		
Germ	147	4.90	10.61	15.60	16.48	2.75		
Bran	306	10.20	10.23	31.30	11.63	8.07		
By-product	540.5	18.02						
Total yield	2972.5	94.08						
Loss	27.5	0.92						
By-product oil recovery %				49.84				
By-product total oil lb/100 cwt				185.92				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 26. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions

8 hrs 25% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	452	15.07	1.07	4.84	11.86	0.58	59.5	.195
Medium grit +24LW	1468	48.93	1.46	21.43	12.85	0.58	56.1	.103
Major grit ***	1920	64.00	1.37	26.27				
Fine grit +34W	144	4.80	4.91	7.07	15.20	0.96	44.4	
Meal +66LW	96	3.20	6.45	6.19	15.65	1.17		
Flour -66LW	250	8.33	4.16	10.40	10.31	1.19	37.5	
Premium product	2410	80.33	2.07	49.93				
Shorts	53	1.77	7.51	3.98	15.12	1.25		
Reddog	37	1.23	12.78	4.73	13.06	3.81		
Germ	182	6.07	16.63	30.27	16.82	2.57		
Bran	316	10.53	10.16	32.11	11.86	8.19		
By-product	588	19.60						
Total yield	2998	99.93						
Loss	2	0.07						
By-product oil recovery %				58.74				
By-product total oil lb/100 cwt								

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 27. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

0.5 hrs 17% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	684	22.80	1.56	10.67	12.13	0.59	60	.147
Medium grit +24LW	1257	41.90	1.18	14.83	12.49	0.49	63.0	.128
Major grit***	1941	64.70	1.31	25.50				
Fine grit +34W	120	4.00	4.75	5.70	15.32	0.87	45	.354
Meal + 66LW	107.5	3.58	6.68	7.18	14.64	1.08		.189
Flour -66LW	154	5.13	6.80	10.47	10.00	1.30	36.9	.235
Premium product	2322.5	77.42	2.10	48.85				
Shorts	74	2.47	7.74	5.73	15.38	1.26		.329
Reddog	27	0.90	12.85	3.47	12.75	3.74		.485
Germ	181	6.03	13.13	23.77	16.20	2.49		.369
Bran	337	11.23	11.84	39.90	12.51	7.29		.695
By-product	619	20.63						
Total yield	2941.5	98.05						
Loss	58.5	1.95						
By-product oil recovery %				59.87				
By-product total oil lb/100 cwt				242.80				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 28. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

0.5 hr 21% MC 110°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	638	21.27	1.16	7.40	11.89	0.77	69.5	.206
Medium grit +24LW	1264	42.13	2.41	30.46	12.34	0.77	55	.145
Major grit***	1902	63.40	1.99	37.86				
Fine grit +34W	122	4.07	5.46	6.66	15.25	0.75	44	
Meal +66LW	82.5	2.75	5.88	4.85	14.79	1.14		
Flour -66LW	158	5.27	5.82	9.20	9.63	1.14	31	
Premium product	2264.5	75.48	2.59	58.57				
Shorts	67	2.23	6.22	4.17	14.33	1.13		
Reddog	22	0.73	12.52	2.75	13.52	3.55		
Germ	224	7.47	12.60	28.22	16.18	1.79		
Bran	334	11.13	10.75	35.91	11.87	7.32		
By-product	647	21.57						
Total yield	2911.5	97.05						
Loss	88.5	2.95						
By-product oil recovery %				54.81				
By-product total oil lb/100 cwt				236.73				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 29. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

0.5 hrs 21% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	591	19.70	1.15	6.80	12.03	0.77	75	.205
Medium grit +24LW	1355	45.17	1.72	23.31	12.42	0.67	64.6	.156
Major grit***	1946	64.87	1.55	30.11				
Fine grit +34W	118.5	3.95	4.42	5.24	15.33	0.66	53.9	
Meal +66LW	67	2.23	5.69	3.81	15.27	1.14		
Flour -66LW	171.5	5.72	5.51	9.45	9.87	1.14	41.4	
Premium product	2303	76.77	2.11	48.61				
Shorts	49	1.63	7.46	3.66	15.29	1.32		
Reddog	33	1.10	11.91	3.93	12.65	3.63		
Germ	183	6.10	16.37	29.96	16.74	2.42		
Bran	333	11.10	10.15	33.80	11.91	8.03		
By-product	598	19.93						
Total yield	2901	96.70						
Loss	99	3.30						
By-product oil recovery %				59.48				
By product total oil lb/100 cwt				237.73				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 30. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs 21% MC 150°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	615	20.50	1.33	8.18	12.10	0.86	52.5	.179
Medium grit +24LW	1346	44.87	1.33	17.90	12.42	0.66	42.3	.237
Major grit***	1961	65.37	1.33	26.08				
Fine grit +34W	100	3.33	5.40	5.40	14.88	0.74	37.1	
Meal +66LW	57	1.90	5.72	3.26	14.26	0.94		
Flour -66LW	147	4.90	5.96	8.76	9.32	1.21	31.1	
Premium product	2265	75.50	1.92	43.5				
Shorts	127	4.23	8.46	10.74	15.25	1.40		
Reddog	31	1.03	11.42	3.54	11.98	4.05		
Germ	159	5.30	18.49	29.40	16.63	2.69		
Bran	288	9.60	10.09	29.06	11.55	8.25		
By-product	605	20.17						
Total yield	2870	95.67						
Loss	130	4.33						
By-product oil recovery %				62.58				
By-product total oil lb/100 cwt				242.36				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 31. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs 17% MC 70°F 3000 gram sample

Fractions	Yield g	%	Crude fat %	Total oil gm	Protein %	Fiber %	Color Agtron**	Tannin % of 1 gm sample
Coarse grit +14W	490	16.33	1.25	6.13	12.27	0.67	67	.221
Medium grit +24LW	1453	48.43	1.34	19.47	12.34	0.57	69.0	.197
Major grit***	1943	64.76	1.32	25.60				
Fine grit +34W	139	4.63	4.52	6.28	14.70	0.75	65.4	
Meal +66LW	93	3.10	6.25	5.81	14.67	1.23		
Flour -66LW	169	5.63	7.25	12.25	10.02	1.34	33.3	
Premium product	2344	78.13	2.13	49.94				
Shorts	78	2.60	8.69	6.78	15.60	1.31		
Reddog	28	0.93	13.68	3.83	12.94	3.79		
Germ	88	2.93	15.72	13.83	16.56	2.42		
Bran	356	11.87	10.98	39.09	11.33	7.48		
By-product	550	18.33						
Total yield	2894	96.47						
Loss	106	3.53						
By-product oil recovery %				55.99				
By-product total oil lb/100 cwt				211.68				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 32. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

0.5 hrs 17% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	789	26.30	1.46	11.52	11.90	0.78	66.2	.229
Medium grit +24LW	1228	40.93	1.37	16.82	12.17	0.59	63.7	.188
Major grit***	2017	67.23	1.41	28.34				
Fine grit +34W	141	4.70	6.54	9.22	15.78	0.96	54.3	
Meal +66LW	2399	79.97	2.30	55.23				
Shorts	91	3.03	7.58	6.90	15.07	1.25		
Reddog	31	1.03	13.29	4.12	12.91	3.42		
Germ	105	3.50	13.25	13.91	16.40	2.38		
Bran	360	12.00	11.93	42.95	12.49	7.33		
By-product	587	19.57						
Total yield	2986	99.53						
Loss	14	0.47						
By-product oil recovery %				55.14				
By-product total oil lb/100 cwt				226.17				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 33. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs 17% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	% of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	571	19.03	0.94	5.36	11.94	0.66	72	.259
Medium grit +24LW	1380	46.00	1.42	19.60	12.70	0.76	58.5	.189
Major grit***	1951	65.03	1.28	24.96				
Fine grit +34W	106	3.53	5.06	5.36	15.09	0.75	57.4	
Meal +66LW	68	2.27	6.32	4.30	15.14	1.11		
Flour -66LW	156	5.20	7.04	10.98	10.19	1.30	32	
Premium product	2281	76.04	2.00	45.60				
Shorts	90	3.00	8.75	7.88	15.83	1.21		
Reddog	37	1.23	10.24	3.79	12.32	3.80		
Germ	93	3.10	16.35	15.21	17.19	2.32		
Bran	345	11.50	11.11	38.33	12.12	7.35		
By-product	565	18.83						
Total yield	2846	94.87						
Loss	154	5.13						
By-product oil recovery %				58.85				
By-product total oil lb/100 cwt				217.27				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 34. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

8 hrs. 17% MC 70°F 3000 gram sample								
Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	642	21.40	1.15	7.38	12.13	0.67	46.1	.272
Medium grit +24LW	1323	44.10	1.43	18.92	12.56	0.76	43.7	.196
Major grit***	1965	65.50	1.34	26.30				
Fine grit +34W	116	3.87	5.59	6.48	15.10	0.84	39	
Meal +66LW	71	2.37	6.07	4.31	14.38	1.12		
Flour -66LW	144	4.80	6.19	8.91	9.56	1.31	41.4	
Premium product	2296	76.53	2.00	46				
Shorts	121	4.03	8.57	10.37	14.90	1.30		
Reddog	27	0.90	11.01	2.92	12.30	3.42		
Germ	132	4.40	16.35	21.58	15.98	2.60		
Bran	325	10.83	11.31	36.76	12.14	7.08		
By-product	605	20.17						
Total yield	2901	96.70						
Loss	99	3.30						
By-product oil recovery %				60.89				
By-product total oil lb/100 cwt				238.66				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 35. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

3.5 hrs 21% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Protein	Fiber	Color Agtron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	678	22.60	0.96	6.51	12.09	0.77	71.7	.321
Medium grit +24LW	1288.5	42.95	1.44	18.55	12.28	0.77	54.7	.043
Major grit***	1966.5	65.55	1.27	25.06				
Fine grit +34W	122	4.07	5.91	7.21	15.76	0.94	53.6	
Meal +66LW	75	2.50	5.92	4.44	15.12	1.22		
Flour -66LW	186	6.20	7.75	14.42	10.49	1.42	19.5	
Premium product	2349.5	78.32	2.18	51.13				
Shorts	56	1.87	8.45	4.73	16.06	1.32		
Reddog	45.5	1.52	12.44	5.66	13.09	2.81		
Germ	78	2.60	13.89	10.83	16.33	2.35		
Bran	384	12.80	11.19	42.97	12.86	7.03		
By-product	563.5	18.78						
Total yield	2913	97.10						
Loss	87	2.90						
By-product oil recovery %				55.66				
By-product total oil lb/100 cwt				213.87				

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* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 36. Yields and Chemical Analyses* of Various Conditioning Treatments of Dry-Milled Grain Sorghum's Nine Fractions.

1.5 hrs. 25% MC 70°F 3000 gram sample

Fractions	Yield	%	Crude fat	Total oil	Pro-tein	Fiber	Color Ag-tron**	Tannin % of 1 gm sample
	g		%	gm	%	%		
Coarse grit +14W	480	16.00	0.87	4.18	11.88	0.58	72.2	.713
Medium grit +24LW	1454	48.57	2.31	33.59	12.44	0.77	51.5	.109
Major grit***	1934	64.47	1.95	37.77				
Fine grit +34W	153	5.16	5.54	8.48	15.56	0.85	47.5	
Meal +66LW	77.5	2.58	5.75	4.46	15.82	1.15		
Flour -66LW	200	6.67	5.94	11.88	10.16	1.25	36	
Premium product	2364.5	78.82	2.65	62.59				
Shorts	75	2.50	8.83	6.62	16.24	1.33		
Reddog	31	1.03	11.19	3.47	12.71	3.41		
Germ	124	4.13	17.41	21.59	16.66	3.01		
Bran	348	11.60	10.78	37.51	12.37	7.87		
By-product	578	19.26						
Total yield	2942.5	98.08						
Loss	57.5	1.92						
By-product oil recovery %				52.5				
By-product total oil lb/100 cwt				230.53				

* On 14% moisture basis including tannin content.

** Discs 33-68.

*** Coarse grit + medium grit.

Table 37. **Analyses of Variance When There Were Significant Interactions Involving the Main Effects (Time of Tempering, Per Cent Moisture, and Temperature of Grain).**

		Mean Square and Significance				
Source of Variation	DF	% Fiber in meal	Major grits %	% Protein in Coarse grits	% of coarse grits	Total oil coarse grits
Tempering time	3	.0269	142.7	.5185	293.5	18.24
Moisture %	2	.0095	3.133	.1501	31.82ns	19.26
Grain Temperature	2	.0138ns	1.26ns	.0419ns	36.59	0.673
TXM	6	.0567**	5.865*	.1055*	34.11ns	3.478
TXG	6	.0124ns	3.736ns	.0315ns	54.42*	11.82*
MXG	4	.0148ns	4.047ns	.0539ns	19.17ns	2.052ns
Error	12	.00883	1.3715	.02412	17.18	3.592
Total	35					

		Mean Square and Significance				
Source of Variation	DF	% Crude Fat in coarse grits	% Crude Fat in Meal	% Fiber Medium grits	% Crude Fat in Shorts	Total Yield
Tempering time	3	.2168	.3619	.00525	1.834	44.15
Moisture %	2	.0857	.0041	.00215	5.689	5.965
Grain Temperature	2	.026ns	.5410	.00001	3.459ns	20.30ns
TXM	6	.0865^{+}	.6253*	.01609**	8.659*	65.68*
TXG	6	.0581ns	.2777	.00567ns	4.220ns	16.76ns
MXG	4	.0168ns	.2986	.00977*	4.882ns	18.46ns
Error	12	.0340	.1685	.00255	1.997	17.36

Table 37. (Continued).

Source of Variation	DF	Mean Square and Significance Shorts %	 Total oil %	 % Premium Product	 % Germ
Tempering Time	3	2.106	7.520	58.57	5.820
Moisture %	2	.3870	.2672	1.908	2.277
Grain Temperature	2	.2514ns	3.320	1.814ns	.0892ns
TXM	6	2.695*	14.27*	10.37*	2.752+
TXG	6	1.930ns	11.59+	3.011ns	.6650ns
MXG	4	.2890ns	6.037ns	3.333ns	.4914ns
Error	12	.8246	4.562	2.572	1.012
Total	35				

Table 38. Analyses of Variance When There are no Significant Interactions (P .05) and Orthogonal Main Effect Trends are Studied.

Source of Variation	DF	Mean Square and Significance % Fiber in Germ	 % Fiber Fine Grits	 % Protein in Bran	 % Protein Medium Grits
Tempering Time	3				
Linear 1		5.534**	.00749ns	5.850**	1.345**
Add. quad 1		.618ns	.004926ns	1.015*	.0554ns
Add. Cubic 1		.756$^+$	.2238**	0.253ns	.2252*

Table 38. (Continued

Source of Variation	DF	% Fiber in Germ	% Fiber Fine Grits	% Protein in Bran	% Protein Medium Grits
Moisture%	2				
Linear 1		.0672ns	.1246*	.0975ns	.00329ns
Add. Quad 1		.0231ns	.00551ns	1.0352*	.00346ns
Grain Temperature	2				
Linear 1		.0005ns	.0417ns	.1041ns	.0900ns
Add. Quad 1		.1225ns	.0000ns	.00642ns	.238ns
TXM	6	.1244ns	.0441ns	.1855ns	.0257ns
TXG	6	.1474ns	.0180ns	.2140ns	.0811ns
MXG	4	.1550ns	.0267ns	.3590ns	.0240ns
Error	12	.2065	.02057	.2027	.03776
Total	35				

Table 38. (Continued).

		Mean Square and Significance					
Source of Variation	DF	% Crude Fat in Flour	% Crude Fat in Major Grits	% Crude Fat in Medium Grits	Agtron Flour	Agtron Fine Grits	Agtron Coarse Grits
Tempering Time	3						
Linear	1	.2854ns	.6700**	.7779**	604.3	441.04**	1177.7**
Add. Quad	1	.5104ns	.1143+	.1801ns	1.044ns	28.23ns	276.1+
Add. Cubic	1	2.850+	.2605*	.0835ns	21.95ns	1.57ns	17.18ns
Moisture %	2						
Linear	1	2.667+	.05904ns	.03530ns	332.3$^+$	98.41ns	122.9ns
Add. Quad	1	6.336*	.05171ns	.08413ns	191.8ns	100.82ns	25.32ns
Grain Temperature	2						
Linear	1	2.185ns	.00960ns	.00121ns	.3038ns	3.375ns	205.9ns
Add. Quad	1	0.00405ns	.00002ns	.00062ns	51.84ns	0.4050ns	71.01ns
TXM	6	1.705ns	.05956ns	.07830ns	66.89ns	60.36ns	59.07ns
TXG	6	1.348ns	.01481ns	.03731ns	51.69ns	34.21ns	62.76ns
MXG	4	0.465ns	.07414ns	.1118ns	35.76ns	69.76ns	79.55ns
Error	12	0.7730	.02924	.06671	91.93	37.99	66.66
Total	35						

Table 38. (Continued).

		Mean Square and Significance					
Source of Variation	DF	Total Oil Germ	Total Oil Premium Product	Total Oil Flour	Total Oil Major Grits	Total Oil Medium Grits	% By-Products
Tempering Time	3						
Linear	1	13.53ns	455.5**	15.08+	97.12*	241.9**	23.19**
Add. Quad	1	213.04*	39.97ns	.2518ns	76.58*	5.847ns	0.0007ns
Add. Cubic	1	62.45ns	148.3+	7.018ns	55.44*	35.57ns	11.36*
Moisture %	2						
Linear	1	71.38ns	14.06ns	18.43+	37.03+	3.308ns	.6018ns
Add. Quad	1	59.46ns	3.622ns	21.64*	24.63ns	23.96ns	6.172+
Grain Temperature	2						
Linear	1	.0770ns	.00457ns	2.053ns	2.196ns	15.47ns	.2205ns
Add. Quad	1	2.443ns	25.22ns	8.750ns	0.0555ns	0.0975ns	.03554ns
TXM	6	53.75ns	75.10ns	8.920ns	24.20ns	13.66ns	2.246ns
TXG	6	18.50ns	10.05ns	2.153ns	4.593ns	29.29ns	1.622ns
MXG	4	34.90ns	43.76ns	0.3305ns	31.76+	47.20+	1.280ns
Error	12	26.11	32.39	3.963	11.01	16.35	1.3640
Total	35						

Table 38. (Continued).

		Mean Square and Significance					
Source of Variation	DF	% Bran	% Flour	% Meal	% Fine Grits	Total Oil Meal	Total Oil Fine Grits
Tempering Time	3						
Linear 1		28.24**	2.392*	.0452ns	17.62**	.03826ns	66.43**
Add. Quad 1		0.6502ns	0.4173ns	1.556**	1.594+	4.104*	.7869ns
Add. Cubic 1		0.0343ns	7.937**	0.0594ns	1.172+	.2194ns	6.035+
Moisture %	2						
Linear 1		0.4482ns	1.556+	.8290*	2.502*	2.774*	14.25**
Add. Quad 1		0.6048ns	0.0268ns	.0953ns	.3108ns	.3528ns	3.667ns
Grain Temperature	2						
Linear 1		0.08046ns	0.1567ns	.0281ns	.00011ns	1.358ns	.5519ns
Add. Quad 1		0.4280ns	2.730*	.1137ns	.4036ns	.36853ns	2.676ns
TXM	6	0.6563ns	0.8713ns	.1965ns	.4911ns	1.136ns	2.106ns
TXG	6	0.8360ns	0.3172ns	.1382ns	.0944ns	.9956ns	.4340ns
MXG	4	0.3576ns	0.3292ns	.0788ns	.1313ns	.6616ns	1.264ns
Error	12	0.8867	0.4384	.1681	.3452	.4962	1.321
Total	35						

Table 38. (Continued).

Source of Variation		DF	Mean Square and Significance Tannin in Course Grits	 % Crude Fat in Bran	
Tempering Time		3			
Linear	1		.06074**	11.14+	(Machine error but are clearly ns).
Add. Quad	1		.02188+	2.724ns	
Add. Cubic	1		.00001ns	6.652ns	
Moisture %		2			
Linear	1		.03420*	7.370ns	.4758ns
Add. Quad	1		.01075ns	0.0855ns	.3418ns
Grain Temperature		2			
Linear	1		.00190ns	2.357ns	.0950ns
Add. Quad	1		.00002ns	2.212ns	.0203ns
TXM		6	.01162ns	1.737ns	.2193ns
TXG		6	.00791ns	2.462ns	.1806ns
MXG		4	.00717ns	4.724ns	.1477ns
Error		12	.005302	2.506	.1746
Total		35			

Table 38. (Continued).

Source of Variation	DF	Mean Square and Significance % Fiber in Bran	 % Fiber Coarse Grits
Tempering Time	3		
Linear	1	38.63**	.00354ns
Add. Quad	1	6.574**	.003101*
Add. Cubic	1	8.593**	.00735ns
Moisture %	2		
Linear	1	.5611ns	.0551**
Add. Quad	1	.0091ns	.0224*
Grain Temperature	2		
Linear	1	1.892+	.00050ns
Add. Quad	1	.3960ns	.03080*
TXM	6	.4776ns	.00979ns
TXG	6	.1139ns	.00158ns
MXG	4	.5359ns	.00857ns
Error	12	.4324	.003776
Total	35		

Table 39. Analysis of Variance and Follow-up When Tempering Time Effective, and Moisture and Grain Temperature Interact. Total Oil from Bran.

Source of Variation	DF	Mean Square and Significance
Tempering Time	3	
Linear	1	607.5**
Add. Quad	1	50.23ns
Add. Cubic	1	159.0*
Moisture %	2	(see Below)
Grain Temperature	2	
TXM	6	24.90ns
TXG	6	53.46ns
MXG	4	(See Below)
Error	12	27.37
Total	35	

Table of Means

Grain Temperature	Moisture %				
	17		21		25
70	35.7	ns	30.4	ns	31.3
	+		ns		ns
110	28.6	ns	31.2	ns	28.8
	ns		ns		+
150	26.0	ns	32.2	ns	37.9

lsd+ = 6.59

Table 40. Tables of Means for Study of Time X Moisture Interactions.

A. % Protein in Coarse Grits

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	12.69	+	12.45	ns	12.48	**	12.01
	*		ns		**		ns
21	12.33	ns	12.37	*	12.03	ns	12.04
	ns		+		+		ns
25	12.42	+	12.65	**	11.86	ns	12.03

ns = nonsignificant, $P > .10$

\+ = significant with $.05 < P \leq .10$

* = significant with $.01 < P \leq .05$

** = significant with $P \leq .01$

B. % Major Grits.

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	70.35	**	75.70	**	68.61	**	64.55
	ns		*		**		ns
21	71.10	+	72.85	**	64.66	ns	65.67
	ns		ns		ns		ns
25	72.13	ns	72.86	**	65.20	ns	65.17

Table 40. (Continued)

C. % Fiber in Meal

%			Time (hrs)				
Moisture	0.5		1.5		3.5		8.0
17	1.21	ns	1.13	**	0.89	*	1.07
	ns		*		**		ns
21	1.27	**	0.96	*	1.16	ns	1.14
	**		**		ns		ns
25	1.00	**	1.24	*	1.04	ns	1.16

D. % Germ

%			Time (hrs)				
Moisture	0.5		1.5		3.5		8.0
17	4.11	ns	4.11	ns	5.20	ns	6.29
	ns		ns		ns		ns
21	3.84	ns	3.33	*	5.91	*	3.18
	ns		+		ns		ns
25	3.91	ns	4.78	ns	6.07	**	3.71

E. % Shorts

%			Time (hrs)				
Moisture	0.5		1.5		3.5		8.0
17	4.72	**	1.10	ns	2.42	ns	2.70
	**		ns		ns		ns
21	2.30	ns	2.19	ns	2.18	ns	2.88
	ns		ns		ns		ns
25	2.22	ns	2.83	ns	2.10	ns	2.80

Table 40. (Continued)

F. % Total Yield

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	59.5	ns	54.7	ns	60.7	ns	59.0
	*		ns		ns		ns
21	51.5	ns	57.0	ns	63.5	ns	56.7
	ns		*		*		ns
25	54.5	**	66.0	**	56.1	ns	56.3

G. % Crude Fat in Shorts

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	7.4	ns	5.6	**	10.8	**	7.4
	+		*		*		ns
21	9.7	ns	10.4	*	7.9	ns	8.3
	ns		ns		ns		ns
25	9.7	ns	8.7	ns	8.3	ns	8.6

H. % Crude Fat in the Meal (See Fig. 19)

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	6.28	ns	6.40	ns	6.42	ns	5.76
	*		ns		*		ns
21	6.99	**	5.99	ns	5.54	*	6.39
	*		ns		*		ns
25	6.09	ns	6.49	ns	6.26	ns	5.91

Table 40. (Continued).

I. % Crude Fat in the Coarse Grits (See Fig. 16)

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	1.38	+	0.98	ns	0.97	ns	1.21
	+		ns		ns		ns
21	1.03	ns	0.89	ns	1.01	ns	1.22
	ns		+		ns		ns
25	1.05	*	0.59	*	1.23	ns	0.99

J. Total Oil From Shorts

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	10.2	*	2.6	*	8.0	ns	6.2
	*		*		ns		ns
21	6.5	ns	6.8	ns	5.2	ns	7.2
	ns		ns		ns		ns
25	6.5	ns	7.4	ns	5.2	ns	7.2

K. % Premium Product

%	Time (hrs)						
Moisture	0.5		1.5		3.5		8.0
17	79.2	**	83.9	**	79.8	*	75.9
	+		ns		**		+
21	81.9	ns	83.2	**	75.9	ns	78.0
	ns		ns		**		ns
25	82.6	ns	81.5	ns	79.6	ns	77.9

Table 40. (Continued).

L. % Fiber in Medium Grits

% Moisture	Time (hrs)						
	0.5		1.5		3.5		8.0
17	0.65	ns	0.66	ns	0.71	ns	0.70
	ns		ns		ns		ns
21	0.68	ns	0.62	**	0.76	*	0.64
	ns		ns		**		**
25	0.65	ns	0.65	*	0.55	**	0.77

Table 41. Means for Study of Interaction Between % Moisture and Grain Temperature. % Fiber in Medium Grits.

Grain Temperature	% Moisture				
	17		21		25
70°F	0.73	*	0.65	ns	0.63
	ns		ns		ns
110°	0.68	ns	0.65	ns	0.68
	ns		ns		ns
150°	0.63	*	0.72	ns	0.66

Table 42. Means for Study of Time X Grain Temperature Interactions.

A. Total Oil From Coarse Grits

Grain	Time (hrs)						
Temperature	0.5		1.5		3.5		8.0
70°F	11.41	*	8.06	ns	6.21	ns	6.97
	ns		ns		ns		ns
110°	10.17	ns	8.12	+	5.19	+	8.28
	ns		ns		**		ns
150°	9.11	ns	7.73	+	10.90	*	5.91

ns = nonsignificant, $P > .10$

\+ = significant, $.05 < P \leq .10$

* = significant, $.01 < P \leq .05$

** = significant, $P \leq .01$

B. % of Coarse Grits

Grain	Time (hrs)						
Temperature	0.5		1.5		3.5		8.0
70°F	27.52	+	34.51	*	20.33	ns	19.67
	ns		ns		ns		ns
110°	29.71	ns	31.53	**	17.65	ns	22.87
	ns		ns		**		ns
150°	32.46	ns	31.69	ns	31.33	**	18.51

Table 43. Per Cent Moisture Interacts with Both Tempering Time and the Grain Temperature. % Fiber in Medium Grits.

A. Time X Moisture (Repeats Table 4 M.)

%	Time						
Moisture	0.5		1.5		3.5		8.0
17	0.65	ns	0.66	ns	0.71	ns	0.70
	ns		ns		ns		ns
21	0.68	ns	0.62	**	0.76	*	0.64
	ns		ns		**		**
25	0.65	ns	0.65	*	0.55	**	0.77

B. Moisture X Grain Temperature.

	Per Cent Moisture				
Temperature	17		21		25
70°F	0.73	*	0.65	ns	0.63
	ns		ns		ns
110°	0.68	ns	0.65	ns	0.68
	ns		ns		ns
150°	0.63	*	0.72	ns	0.66

Table 44A. Effect of tempering time on yield of fine grits.

Time hrs	Yield %
0.5	2.41
	ns
1.5	2.46
	*
3.5	3.66
	+
8.0	4.14

Table 44B. Effect of tempering moisture on the yield of fine grits.

Moisture %	Yield %
17	2.78
	*
21	3.30
	*
25	4.43

Table 45. Effect of tempering time on yield of meal.

Time hrs		Yield %	
0.5		2.25	
		+	
1.5		2.62	
		ns	
3.5		2.84	
	ns	+	ns
8.0		2.47	

Table 46A. Effect of tempering time on yield of flour.

Time hrs		Yield %	
0.5		5.30	
		*	
1.5		4.34	
	ns	*	*
3.5		5.78	
	ns	ns	
8.0		5.54	

Table 46B. Effect of temperature of grain on yield of flour.

Temperature (F°)		
70		5.13
		+
110		5.63
	ns	+
150		4.96

Table 47. Effect of tempering time on yield of bran.

Time hrs.		Yield %	
0.5		8.99	
		ns	
1.5		9.54	
	*	ns	
3.5		10.27	
		*	*
8.0		11.38	

Table 48. Effect of tempering time on yield of by-products.

Time hrs		Yield %
0.5		1.58
		ns
1.5		0.43
	ns	*
3.5		2.31
		ns
8.0		3.09

Table 49. Effect of tempering time on fat content of coarse grits.

Time hrs			Fat %	
0.5			1.15	
			*	
1.5			0.82	
		ns	*	
3.5			1.07	
	ns		ns	
8.0			1.16	

Table 50. Effect of tempering time on fat content of medium grits.

Time hrs			Fat %	
0.5			1.34	
			ns	
1.5			1.18	
		ns	ns	
3.5			1.30	
	*		*	*
8.0			1.64	

Table 51. Effect of temperature of grain on fat content of meal.

Temperature (F°)		Fat %
70		6.01
		ns
110		6.19
	+	ns
150		6.44

Table 52. Effect of tempering moisture on fat content of flour.

Mositure %		Fat %
17		5.70
		*
21		6.92
	+	ns
25		6.36

Table 53. Effect of tempering time on fat content of bran.

Time hrs			
0.5		8.92	
		+	
1.5		10.53	
	+	ns	
3.5		10.28	
		ns	ns
8.0		10.92	

Table 54. Effect of tempering time on total oil of medium grits.

Time hrs			Total oil grams	
0.5			16.50	
			ns	
1.5			14.40	
		ns	ns	
3.5			17.99	
	*		ns	*
8.0			22.07	

Table 55. Effect of tempering time on total oil of major grits[a].

Time hrs			Total oil grams	
0.5			26.73	
			*	
1.5			22.37	
		ns	ns	
3.5			24.43	
	ns		*	*
8.0			29.12	

a Coarse grits + medium grits

Table 56. Effect of tempering time on total oil of fine grits.

Time hrs		Total oil grams	
0.5		3.63	
		ns	
1.5		3.25	
	*	*	
3.5		5.37	
		*	*
8.0		6.81	

Table 57. Effect of tempering moisture on total oil of fine grits.

Moisture %	Total oil grams
17	3.77
	*
21	5.22
	ns
25	5.31

Table 58. Effect of tempering time on total oil of meal.

Time hrs		Total oil grams	
0.5		4.34	
		ns	
1.5		4.48	
	+	ns	
3.5		4.94	
		ns	+
8.0		5.20	

Table 59. Effect of tempering moisture on total oil of meal.

Moisture %	Total oil grams
17	5.01
	ns
21	4.88
	+
25	4.33

Table 60. **Effect of tempering moisture on total oil of flour.**

Moisture %		Total oil grams
17		8.46
		*
21		10.98
	*	ns
25		10.22

Table 61. Effect of tempering time on total oil of premium products[a].

Time hrs			Total oil grams	
0.5			44.50	
			ns	
1.5			39.32	
		ns	ns	
3.5			45.12	
	*		*	*
8.0			51.24	

a Coarse grits, medium grits, fine grits, meal, flour

Table 62. Effect of tempering time on total oil of germ.

Time hrs			Total oil grams	
0.5			19.20	
			ns	
1.5			19.11	
		*	*	
3.5			26.02	
	ns		*	ns
8.0			20.50	

Table 63. Effect of tempering time on total oil of bran.

Time hrs		Total oil grams	
0.5		24.03	
		*	
1.5	*	32.22	
		ns	
3.5		31.74	ns
		*	
8.0		37.38	

Table 64. Effects of tempering time, tempering moisture and grain temperature on fiber content of coarse grits.

Time	Mean	Moisture %	Mean	Heat	Mean
8.0 hrs	0.726	17	0.755	110°	0.731
	ns		*		*
1.5 hrs	0.701	25	0.659	70°	0.673
	ns		ns		ns
0.5 hr	0.700	21	0.654	150°	0.664
	*				
3.5 hrs	0.633				
lsd*=0.063		lsd*=0.055		lsd*=0.055	

Table 65. Effect of tempering time on fiber content of fine grits.

Time hrs	Fiber %
0.5	0.83
	ns
1.5	0.68
	*
3.5	0.93
	ns
8.0	0.80

Table 66. Effect of tempering moisture on fiber content of fine grits.

Moisture %		Fiber %
17		0.73
		ns
21		0.83
	*	ns
25		0.88

Table 67. Effect of tempering time on fiber content of germ.

Time hrs		Fiber %	
0.5		3.37	
		ns	
1.5		3.44	
	*	*	
3.5		2.64	
		ns	*
8.0		2.44	

Table 68. Effect of tempering time on fiber content of bran.

Time hrs		Fiber %
0.5		9.91
		ns
1.5		10.25
	*	*
3.5		7.79
		ns
8.0		7.55

Table 69. Effect of tempering time on tannin content of coarse grits.

Time hrs			Tannin % in 1 gm sample	
0.5			0.19	
			ns	
1.5			0.18	
		ns	ns	
3.5			0.17	
	*		*	*
8.0			0.29	

Table 70. Effect of tempering moisture on tannin content of coarse grits.

Moisture %	Tannin % in 1 gm sample
17	0.18
	ns
21	0.18
	*
25	0.26

Table 71. Effect of tempering time on protein content of medium grits.

Time hrs		Protein %	
0.5		12.85	
		ns	
1.5		12.93	
	*	*	
3.5		12.57	
		ns	*
8.0		12.41	

Table 72. Effect of tempering time on protein content of flour.

Time hrs			Protein %	
0.5			10.52	
			ns	
1.5			10.55	
		*	*	
3.5			9.81	
	*		ns	*
8.0			9.95	

Table 73. Effect of tempering time on protein content of bran.

Time hrs		Protein %
0.5		11.03
		ns
1.5		11.17
	*	*
3.5		11.88
		ns
8.0		12.07

Table 74. Effect of tempering moisture on protein content of bran.

Moisture %		Protein %
17		11.60
		ns
21		11.30
	ns	+
25		11.72

Table 75. Effect of tempering time on agtron color of coarse grits.

Time hrs		Agtron reading	
0.5		49.01	
		ns	
1.5		56.17	
	*	ns	
3.5		62.34	
		ns	*
8.0		65.80	

Table 76. Effect of tempering time on agtron color of fine grits.

Time hrs				
0.5			41.72	
			ns	
1.5			41.32	
		ns	ns	
3.5			43.01	
	*		*	*
8.0			50.24	

Table 77. Effect of tempering moisture on agtron color of flour.

Moisture %		
17		23.11
		ns
21		21.93
	+	+
25		30.55

DISCUSSION

DISCUSSION

I. The following variables produced no main effects nor any interactions involving any of the three introduced variables: time of tempering, percent moisture, or heating of the grain:

(1) % M grits. (2) Agtron on M grits.

(3) tannin in M grits. (4) % crude fat in F grits.

(5) % protein in F grits. (6) % protein in Meal.

(7) % fiber in flour. (8) % protein in shorts.

(9) % fiber in shorts. (10) % crude fat in germ.

(11) % protein in germ.

II. Yield %

1. Yield of Coarse Grits + 14W

It was affected by interaction of heating temperature of the grain and tempering time (Table 42B, Fig. 2).

Interaction effects:

The highest yield resulted when the grain was tempered for 1.5 hours at the grain temperature of 70°F, the lowest yield for 8 hours at 150°F. It proves that lower grain temperature interacting with shorter tempering time is more productive in coarse grit yield.

The common tendency among the three different grain temperatures was that the longer treaments resulted in less yield (see ref. A, B, C).

The maximum yield of C. G. can be obtained under these conditions:

70°F   1.5 hrs.

Reference: A. Yields of major grits

B. Yields of premium products

C. Yields of total products

2. Yield of Major Grits

(Coarse grits + 14W, Medium Grits - 14W, + 24LW)

It was affected by interaction of tempering time and moisture (Table 40B, Fig. 3).

Interaction effects:

The 1.5 hours of tempering at 17% tempering moisture produced the highest yield of major grits; while 8 hours at 17% tempering moisture the lowest. It was also significant that 1.5 hours of tempering produced more major grits than any other tempering time at any moisture level. Shorter tempering time led to a greater yield than long tempering time did (see ref. A, B, C, D).

The maximum yield of M. G. can be obtained under these conditions:

17% M - 1.5 hours

Reference: A. Yields of coarse grits

B. Yields of premium products

C. Yields of total products

D. Yields of meal

In dry-milling practice, the yields of fine grits, meal, flour should be curtailed to a minimum, in order to produce sufficient yield of large grit products.

3. Yield of Fine Grits - 24LW, + 34W

It was affected by both tempering time and moisture without interaction (Table 44A,B,Fig. 4, 5).

The time, moisture effects:

The yield of fine grits increased in proportion to the increasing in either time or moisture. The highest yield of fine grits resulted after 8 hours of grain tempering, or when 25% moisture level was achieved. The lowest yield of fine grits resulted after 0.5 hour of grain tempering, or when 17% moisture level was achieved (see ref. A, B, C).

These indicate: Long tempering treatment imports more mellowness to the grain endosperm and is detrimental to the production of grits.

The minimum yield of F. G. can be obtained under these conditions:

-- -- 0.5 hr. or 1.5 hr. (small difference)
or 17% M -- --

Reference: A. Yield of coarse grits
B. Yield of premium products
C. Yield of total products

4. Yield of Meal - 34W, + 66W

It was affected by tempering time, and the trend was strongly, orderly quadratic (Table 45, Fig. 6).

The time effect:

The 3.5 hours of tempering produced the highest yield of meal, which is not desirable in dry-milling practice, while the 0.5 hour produced the lowest yield (see ref. 1, 2).

The minimum yield of meal can be obtained under these conditions:

--	--	0.5 hr.

Reference: Yield of coarse grit
Yield of fine grit

5. Yield of Flour - 66W

There are no interactions among tempering time, tempering moisture and heating temperature of the grain on the yield of flour. The yield of flour was related to the tempering time with a cubic trend and heating temperature of the grain with a quadratic trend (Table 46A , Fig. 7, 8).

The time effects:

The 1.5 hours of tempering produced the least amount of flour (see ref. A, B, C, D).

The temperature effect:

The grain temperature of 70°F, as well as 150°F, produced less flour than that of 110°F.

The minimum yield of flour can be obtained under these conditions:

	--	--	1.5 hrs.
OR	--	70°F	--
	--	150°F*	--

*70°F is better than 150°F, since it takes energy to heat the grain.

Reference: A. Yield of coarse grits
B. Yield of total products
C. Yield of fine grits
D. Yield of meal

6. Yield of Premium Products

(Coarse grits, medium grits, fine grits, meal, flour)

It was affected by both tempering time and levels of tempering moisture with interaction (Table 40K, Fig. 9).

Interaction effects:

The highest yield of premium products resulted after 1.5 hours of grain tempering at 17% tempering moisture. The second highest yield resulted after 1-5 hours of grain tempering but at a higher tempering moisture level 21%. Generally speaking, there was a decrease in yield, as tempering time simultaneously increased (see ref. A, B, C).

The maximum yield of premium products can be obtained under these conditions:

17% M - 1.5 hrs.

Reference: A. Yield of coarse grits
B. Yield of major grits
C. Yield of total products

7. Yield of Shorts

(Grits, Germ, Bran)

A low yield of shorts is preferred in dry-milling practice. It means less premium endosperm material will be tailed to the feed fraction. This is on account of the main component of shorts is grits.

The yield of shorts was affected by both tempering time and level of moisture with interaction (Table 40E

Interaction effects:

The very lowest yield (1.10%) resulted at 17% moisture after the grain was tempered for 1.5 hours. This finding is strikingly consistent with those of yield of major grits, premium products (see Ref. A, B).

The minimum yield of shorts can be obtained under these conditions:

17% M -- 1.5 hrs.

Reference: A. Yield of major grits

B. Yield of premium products

8. Yield of Germ

It was affected by both tempering time and moisture with interaction (Table 40D, Fig. 10, 11).

Interaction effects:

With 17% tempering moisture, the yield after the grain was held for 8 hours was the highest yield among those of 0.5, 1.5, 3.5 hours of tempering. Also it was the maximum yield among all tempering treatments.

As tempering moisture is increased to 21% or 25%, the time required for the highest yield is decreased to 3.5 hours tempering.

The 17% tempering moisture could (see ref. 1) lead to a germ yield as high as 25% tempering moisture could, and the latter involves more water and drying with which are undesirable.

The 21% tempering moisture always produced the poorest yield of germ among three tempering moisture levels, independent of the tempering time.

The author concludes that (1) the germ yield increases with tempering time (2) tempering moisture has little effect except 21% moisture always produced the lowest germ yield. Grain with a lower tempering moisture level, 17% could degerm as well as grain with a high tempering moisture level, 21%, 25%.

The maximum germ yield can be obtained under these conditions:

	17% M	-	8 hours
second choice	25%	-	3.5 hours

9. Yield of Bran

It was affected only by tempering time. The trend is strongly and clearly linear (Table 47, Fig. 12).

The time effect:

The 8 hours of tempering produced the highest yield: while 0.5 hour the lowest (see ref. A, B, C).

The maximum yield of bran can be obtained under these conditions:

--	--	8 hrs.
--	--	3.5 hrs.

Reference: A. Yield of by-products

B. Fiber content of Bran

C. Fiber content of germ

10. Yield of By-Products

(Shorts, Red dog, Germ, Bran)

It was only affected by tempering time. The trend was less linear than that for bran yield because of the presence of other fractions other than bran fraction (Table 48, Fig. 13).

The time effect:

Eight hours of tempering produced the highest yield of by-products, while 1.5 hours persistently produced the lowest one (see ref. A).

The maximum yield of by-products can be obtained under these conditions:

--	--	8 hrs.
--	--	1.5 hrs.

Reference: A. Yield of Bran

11. Yield of Total Products

It was affected by both tempering time and moisture with interaction (Table 40F).

Interaction effects:

There was a pronounced peak of total yield after the grain was tempered for 1.5 hours at 25% moisture level (see ref. A).

The time effect:

Generally speaking, the longest tempering time, 8 hours, resulted in less yield of total products.

The maximum yield of total products (i.e. the minimum loss) can be obtained under these conditions:

25% -- 1.5 hrs.

Reference: Yield of premium products

III. Fat Content %

1. Fat Content of Coarse Grits + 14W

It was affected by tempering time and interactions between tempering time and moisture levels. The trend was cubic (Table 40_1, 49, Fig. 14).

Interaction effects:

The 1.5 hours of tempering almost always produced the lowest fat content (below 1%) of coarse grits among the four different tempering periods. The lowest fat content of coarse grits resulted when grain was tempered for 1.5 hrs. at 25% moisture level.

The time effect:

There was an exceptional low fat content (below 1%) when the grain was tempered for 1.5 hours (check chemical analyses tables 16, 17, 18, 19, 20, 24, 33, 35, 36). After 1.5 hours of tempering, the fat content gradually increased. Then, from 3.5 hrs. to 8 hrs., the fat content leveled off (see ref. A, B, C). The two extremes 0.5 hour and 8 hours of tempering time exerted the same effect on fat content of coarse grit.

The minimum fat content of coarse grits can be obtained under these conditions:

— — 1.5 hrs.

Reference: A. Fat content of medium grits

B. Total oil of major grits

C. Total oil of premium products

2. Fat Content of Medium Grits - 14W, + 24LW

It was affected by tempering time. Unlike the fat content of coarse grits, the trend was linear (Table 50, Fig. 15).

The time effect:

Increases in tempering time proportionally increased the fat content of medium grits. The lowest fat content resulted when the grain was tempered for 1.5 hours; the highest, 8 hours. This result was the same as that for the fat content of coarse grits (see ref. A, B, C).

The minimum fat content of medium grits can be obtained under these conditions:

— — 1.5 hrs.

Reference: A. Fat content of coarse grits

B. Total oil of major grits

C. Total oil of premium products

3. Fat Content of Meal - 34W, + 66W

It was affected by (1) heating temperature of the grain and (2) interaction of tempering time and moisture (Tables

51, 40H, Fig. 16).

The temperature effect:

Increases in grain temperature proportionally increased the fat content. The trend was significantly linear. The lowest fat content resulted when the grain was cold tempered at 70°F.

Interaction effects:

At either 17% or 25% moisture level, the tempering time had no discernible effect on fat content of meal.

At 21% tempering moisture, the highest fat content occurred after 0.5 hour of grain tempering, while the lowest after 3.5 hours. Generally speaking, longer tempering time tended to decrease the fat content in meal.

The minimum fat content of meal can be obtained under these conditions:

-- 70°F --

OR

21% M -- 3.5 hrs.

4. Fat Content of Flour - 66W

It was affected by tempering moisture (Table 52; Fig. 17). The lowest fat content resulted when the grain was tempered at 17% moisture content; the highest, at 21% (moisture content). The reason for 21% tempering moisture producing the highest fat content of flour could be explained as follows: No matter how long the tempering time was, 21% tempering moisture always produced the poorest yield of germ. This also means many a whole-piece germ was reduced to small particle size by the impaction of pin mill and mixed with flour fraction (see ref. A).

The minimum fat content of flour can be obtained under these conditions:

17% M -- --

Reference: Yield of Germ

5. Fat Concent of Shorts

(Grits, Germ, Bran)

It was affected by tempering time and moisture with interaction (Table 40G).

Interaction effects:

As tempering moisture was increased to a next higher level, of which the maximum fat content occurred at a shorter tempering time than that for original lower tempering moisture. The lowest fat content of shorts occurred at 17% moisture content when the grain was tempered for 1.5 hours (see ref. A, B, C).

The minimum fat content of flour can be obtained under these conditions:

17% M -- 1.5 hrs.

Reference: A. Fat content of coarse grits

B. Fat content of medium grits

C. Fat content of flour

6. Fat Content of Bran

It was affected by tempering time, and that effect showed no trend (Table 53, Fig. 18).

The time effect:

But the supplemental ANOVA indicated a significant linear trend (i.e. as tempering time increased, the fat content of bran proportionally increased). This indicates longer treatment resulted in breaking more germ whose oil contaminated the bran fraction. The same thing happened in fat contents of coarse grits and medium grits (see ref. A, B). The lowest fat content of bran occurred when the grain was tempered for 0.5 hour.

The minimum fat content of bran can be obtained under these conditions:

--	--	0.5 hour

Reference: A. Fat content of coarse grits

B. Fat content of medium grits

IV. Total oil gram = yield gm x fat %

1. Total oil of coarse grits + 14W

It was affected by interaction between tempering time and heating temperature of the grain (Table 42A).

Interaction effects:

The lowest amount of total oil resulted when grain was tempering for 3 hrs. at the temperature of 110°F. The reason for low amount of total oil at long tempering (like 3.5 hrs.

8 hrs.) was that very poor yield of coarse grits was produced by long tempering. That nullified the effect of increasing fat content of coarse grits at long tempering times. The amount of total oil of coarse grits was mainly influenced by its component the yield of coarse grits, rather than the other component, the fat content of coarse grits.

A minimum amount of total oil of coarse grits can be obtained under these conditions:

-- 110°F -- 3.5 hrs.

Reference: Yield of coarse grits
Fat content of coarse grits

2. Total oil of Medium Grits - 14W, + 24LW

It was affected by tempering time; the trend is linear (Table 54, Fig. 19).

The time effect:

The lowest total oil amount resulted when the grain was tempered for 1.5 hrs. The shorter the tempering time was, the less amount of oil was obtained. The amount of total oil was mainly influenced by the component, the fat content of medium grits only (see Fig. 15, Fig. 19 and Fig. 15 had a very similar straight line).

A minimum amount of total oil of medium grits can be obtained under these conditions:

-- -- 1.5 hrs.

Reference: Fat content of medium grits

3. Total Oil of Major Grits

(Coarse grits + 14W, Medium Grits - 14W, + 24LW)

It was affected by tempering time. More points would be needed before a definite trend would be determined (Table 55, Fig. 20).

The time effect:

No matter what the trend was the 1.5 hours of tempering undoubtedfully produced the least amount of oil, while 8 hours produced the most (see ref. A, B).

A minimum amount of total oil of major grits can be obtained under these conditions:

-- -- 1.5 hrs.

Reference: A. Total oil of medium grits
B. Total oil of premium products

4. Total Oil of Fine Grits + 34W

It was affected by both tempering time and moisture without interactions (Table 56, 57 , Fig. 21, 22).

The time effect:

Total oil increased linearly and significantly with increasing tempering time. The least amount of total oil of fine grits resulted when the grain was tempered for 1.5 hrs. (see ref. A).

The moisture effect:

Total oil increased linearly significantly with increasing tempering moisture. The least amount of total oil of fine grits resulted at 17% tempering moisture.

A minimum amount of total oil of fine grits can be obtained under these conditions:

--	--	1.5 hr.

OR

17% M	--	--

Reference: A. Total oil of medium grits

5. <u>Total Oil of Meal - 34W, + 66W</u>

It was affected by both tempering time and moisture without interaction (Table 58, 59, Fig. 23, 24).

The time effect:

There was a cubic trend in the time effect. The lowest amount of total oil occurred after 0.5 hour of grain tempering, the highest, after 8 hours.

The moisture effect:

There was a linear trend in the moisture effect. The lowest amount of total oil occurred at 25% tempering moisture, while the highest at 17%.

A minimum amount of total oil of meal can be obtained under these conditions:

--	--	0.5 hr.

OR

25%	--	--

Reference: A. Fat content of flour

B. Fat content of shorts

6. Total Oil of Flour - 66W

It was affected only by tempering moisture (Table 60, Fig. 25). The trend was quadratic and was almost identical to that for fat content of flour (see Fig. 17).

The moisture effect:

The lowest amount of total oil resulted at 17% tempering moisture.

A minimum amount of total oil of flour can be obtained under these conditions:

17% M   --   --

Reference: Fat content of flour

7. Premium Products

(Coarse Grits, Medium Grits, Fine Grits, Meal, Flour)

It was affected by tempering time and there appeared to be a cubic component to the over-all trend which was linear and upward with increasing tempering time (Table 61, Fig. 26).

The time effect:

The lowest amount of total oil resulted when the grain was tempered for 1.5 hours (see ref. A).

A minimum amount of total oil of premium products can be obtained under these conditions:

--   --   1.5 hrs.

Reference: A. Total oil of major grits

8. Total Oil of Shorts

(Grits, Germ, Bran)

It was affected by both tempering time and moisture with interaction (Table 40J).

Interaction effects:

At 17% tempering moisture, the maximum and minimum amount of total oil of shorts resulted when the grain was tempered for 0.5 and 1.5 hours. One hour difference can change the amount of total oil from maximum to minimum. It again indicated that 1.5 hours was the critical tempering time for the successful germ-removal by impacting operation (see ref. A, B, C, D, E).

A minimum amount of total oil of shorts can be obtained under these conditions:

17% M -- 1.5 hrs.

Reference:
A. Fat content of coarse grits
B. Fat content of medium grits
C. Fat content of shorts
D. Total oil of major grits
E. Total oil of premium products

9. Total Oil of Germ

It was affected by tempering time. The trend was quadratic (Table 62, Fig. 27).

The time effect:

The 3.5 hours of tempering produced the maximum amount of total oil. 3.5 hours of tempering generally produced the highest yield of germ among the different periods of tempering times (ref. A).

A maximum amount of total oil of germ can be obtained under these conditions:

--	--	3.5 hrs.

Reference: A. Yield of germ

10. Total Oil of Bran

It was affected by tempering time and its interaction with heating temperature of the grain.

The time effect:

As tempering time increased, the amount of total oil proportionally increased (Table 63, Fig. 28). The minimum amount of total oil of bran resulted when the grain was tempered for 0.5 hour (see ref. A, B).

Interaction effect:

The minimum amount of total oil resulted when grain was tempered at 17% moisture and 150°F temperature (Table 39).

A minimum amount of total oil of bran can be obtained under these conditions:

--	--	0.5 hr.

OR

17% M	150°F	--

Reference: A. Yield of bran
B. Fat content of bran

V. Fiber Content %

1. Fiber Content of Coarse Grits + 14W

Fiber content of coarse grits was affected by heating temperature of the grain, tempering time and moisture. But they did not interact. Twenty-one percent tempering moisture, 150°F grain temperature, and 3.5 hours tempering time respectively produced the lowest fiber content (Table 64).

A minimum fiber content of coarse grits can be obtained under these conditions:

	21% M	--	--
OR	--	150°F	--
OR	--	--	3.5 hrs.

Reference: A. Fiber content of medium grits

2. Fiber Content of Medium Grits - 14W, + 24LW

All three variables, tempering time and moisture, heating temperature of the grain were involved in interactions (Table 43A, B). There was no apparent trend.

Interaction effects of tempering moisture and grain temperature:

The lowest fiber content of medium grits resulted when either the grain was heated to the temperature of 150°F at 17% moisture content or cold-tempered, 70°F, at 25% moisture content. A product of low fiber content resulted when the grain was cold tempered, as long as the tempering moisture content was sufficient.

Interaction effects of tempering moisture and time:

The lowest fiber content of medium grits resulted when the grain was tempered for 3.5 hours at 25% moisture level.

A minimum fiber content of medium grits can be obtained under these conditions:

	25% M	--	3.5 hrs.
OR	25% M	70°F	--
OR	17% M	150°F	--

Reference: A. Fiber content of coarse grits

3. Fiber Content of Fine Grits - 24LW, + 34W

The tempering time and moisture affected the fat content of fine grits by exerting a cubic and linear trends upon it (Table 65, 66, Fig. 29, 30).

Interaction effects:

The lowest fiber content of fine grits resulted when either the grain was held for 1.5 hours or was tempered at 17% moisture content.

Unlike the case of coarse grits and medium grits. It was generally true that shorter time or lower moisture level resulted in less fiber content of fine grits.

A minimum fiber content of fine grits can be obtained under these conditions:

17% M	--	--
--	--	1.5 hrs.

Reference: Fiber content of coarse grits
Fiber content of medium grits

4. Fiber Content of Germ

Fiber content of germ was affected by tempering time. The overall effect of tempering time was significantly linear, despite the supplementary ANOVA indicated a weak cubic trend (Table 67, Fig. 31).

The time effect:

The lowest fiber content of germ resulted after 8 hours of grain tempering; the highest after 0.5 hour. The longer tempering time (8 hours), could lead to a higher yield of bran (ref. A, B). Therefore, the distribution of bran over other fractions was curtailed. So the fiber content of germ was also correspondingly reduced.

A minimum fiber content of germ can be obtained under these conditions:

--	--	8 hrs.

Reference: A. Yield of bran

B. Fiber content of bran

5. Fiber Content of Bran

Fiber content of bran was affected by tempering time. The ANOVA indicated a significant ($P < 0.01$) cubic trend. A graph with only 4 points was not very convincing since either straight line or cubic curve could possibly be the answer. Therefore, no lines or curves were drawn among the points Table 68, Fig. 32).

The time effect:

The two shorter tempering times, especially the 1.5 hour one, resulted in a manifestly higher percent fiber in bran than did the two long tempering times. The 1.5 hours of tempering produced the highest (purest) fiber content of bran. Possible reason for the low fiber content of bran at long tempering time is that it could lead to a higher yield of bran (Fig.12), but at the expense of bran purity. Foreign materials, like fat, protein, were brought in during the tempering process (Fig. 18, 38), and diluted the fiber content of the bran (ref. A, B, C).

A maximum fiber content of bran can be obtained under these conditions:

-- -- 1.5 hrs.

Reference: A. Yield of bran
B. Fat content of bran
C. Protein content of bran

VI. Tannin Contents

Most of the tannin is found in bran and could be removed by peeling off bran out of the grain.

The tempering variables:

Moisture, temperature and time did not affect the tannin content of medium grits but the coarse grits.

1. Tannin Content of Coarse Grits + 14W

Tannin content of coarse grits was affected by tempering time and moisture without interaction.

The time effect:

Tempering time exerted a quadratic trend upon the tannin content of coarse grits. From 0.5 to 3.5 hrs., increases in tempering time gradually decreased the tannin content until it reached the lowest point at 3.5 hrs. From 3.5 to 8 hrs., increases in tempering time substantially increased the tannin content until it reached the highest point at 8 hrs. (Table 69, Fig. 33).

The reason for increasing tannin content resulting from long temper was probably due to the co-adhesion between bran and endosperm (ref. A).

The moisture effect:

Tempering moisture exerted a quadratic trend on the tannin content of coarse grits. Seventeen percent and 21% tempering moistures had the same effect on the tannin content, while 25% tempering moisture had the coarse grits had the highest tannin content (Table 70, Fig. 34). A hypothetical explanation was that the co-adhesion between bran and endosperm through the hydrogen bond of excessive moisture was attributed to the increasing tannin content at high level of moisture.

A minimum tannin content of coarse grits can be obtained under these conditions:

17% OR 21%	--	--
OR		
--	--	1.5 hr. or 3.5 hrs. Ns.

Reference: A. Fat content of coarse grits

VII. Protein Content %

1. Protein Content of Coarse Grits + 14W

Protein content of coarse grits was affected by tempering time and moisture with interaction (Table 40A).

Interaction effect:

It was hard to see a pattern trend. Since small differences were adjudged significant at or beyond the 10% level. It was generally true that longer tempering time resulted in less protein content and (ref. A, BO the tempering moisture had very little effect. The probable reason for the loss of protein content was that the hydrolysis of H_2O-soluble proteins was more pronounced when the grain was long-tempered. All the protein contents of coarse grit were almost the same when the grain was tempered for 8 hours, despite the moisture levels. The lowest protein content of coarse grits resulted when the grain was tempered for 0.5 hr. at 17% moisture level.

A maximum protein content of coarse grits can be obtained under these conditions:

17% M -- 0.5 hr.

Reference: A. Protein content of medium grits
B. Protein content of flour

2. Protein of Medium Grits - 14W, + 24LW

Protein content of medium grits was affected by tempering time and the trend was linear (Table 71, Fig. 35).

The time effect:

It was generally true that longer tempering time resulted in less protein content. The same result as to those of coarse grits and flour (ref. A, B). The highest protein content of medium grits resulted when the grain was tempered for 1.5 hrs., the lowest, for 8 hrs.

A maximum protein content of medium grits can be obtained under these conditions:

-- -- 1.5 hrs.

Reference: A. Protein content of coarse grits

B. Protein content of flour

3. <u>Protein Content of Flour - 66W</u>

It was affected by tempering time and that effect showed no trend (Table 72, Fig. 36).

The time effect:

It seemed obvious that the two lower tempering times were equal in effects on protein content of flour, and were higher in that regard than were the equally low two tempering times (ref. A, B, C). The highest protein content occurred when the grain was tempered for 1.5 hours.

A maximum protein content of flour can be obtained under these conditions:

-- -- 1.5 hrs.

Reference: A. Protein content of coarse grits

B. Protein content of medium grits

C. Protein content of bran

4. Protein Content of Bran

Protein content of bran was affected by tempering time and moisture without interaction.

The time effect:

The result was just contrary to those of coarse grits, medium grits and flour. Longer tempering time resulted in higher protein content (Table 73, Fig. 37). The lowest protein content of bran occurred when the grain was tempered for 0.5 hr.; while the highest for 8 hrs. (ref. A, B, C).

The moisture effect:

There was a minimum protein content of bran when the grain was tempered at 17% moisture level (Table 74, Fig. 38).

A minimum protein content of bran can be obtained under these conditions:

--	--	0.5 hr.

OR

21% M	--	--

Reference: A. Protein content of coarse grits
B. Protein content of medium grits
C. Protein content of flour

VIII. Agtron Color Reading

1. Agtron Color of Coarse Grits + 14W

Agtron color of coarse grits was affected by tempering time and the trend was strongly quadratic (Table 75, Fig. 39).

The time effect:

Increased in tempering time steadily increased the readings of agtron color of coarse grits (ref. A). That means that a brighter product was obtained, when the grain was tempered for a longer period. The reading at 8 hours of tempering outnumbered the reading at 0.5 hour of tempering by 15 difference.

A maximum reading of agtron color of coarse grits can be obtained under these conditions:

-- -- 8 hrs.

Reference: A. Agtron color of fine grits

2. Agtron Color of Fine Grits - 24LW, + 34W

Agtron color of fine grits was affected by tempering time. The trend was strongly linear (Table 76, Fig. 40).

The time effect:

Increases in tempering time steadily increased the reading of agtron color (ref. A). The reading of 8 hours of tempering surpassed the one of 0.5 hr. of tempering by 9 difference of reading.

A maximum reading of agtron color of fine grits can be obtained under these conditions:

-- -- 8 hrs.

Reference: A. Agtron color of coarse grits

3. Agtron Color of Flour - 34W, - 66W

Agtron color of flour was affected by tempering moisture, and the trend was quadratic (Table 77, Fig. 41).

The moisture effect:

Twenty-one percent tempering moisture had the lowest reading of agtron color of flour, while 25% had the highest one.

A maximum reading of agtron color of flour can be obtained under these conditions:

25% M -- --

SUMMARY

Table 78. Summary of preferred and unpreferred conditioning treatments upon yields %, Fat %, Total oil gram, Fiber %, tannin %, protein %, agtron color.

I. Yield%		Preferred				Unpreferred				
		Moisture %	Temperature F°	Time hrs		Moisture %	Temperature F°	Time hrs	Table	Figure
Coarse grits	Max	--	70	1.5	Min	--	150	8	42_B	2
Major grits	Max	17	--	1.5	Min	17	--	8	40_B	3
Fine grits	Min	17	--	1.5	Max	25	--	--	$44_{A,B}$	4,5
					or	--	--	8		
Meal	Min	--	--	0.5	Max	--	--	3.5	45	6
Flour	Min	--	70,150	--	Max	--	110	--	$46_{A,B}$	7,8
	or	--	--	1.5	or	--	--	3.5		
Premium products	Max	17	--	1.5	Min	17	--	8	40_K	9
					or	21	--	3.5		
Shorts	Min	17	--	1.5	Max	17	--	0.5	40_E	
Germ	Max	17	--	8	Min	21	--	8	40_D	10, 11
	2nd Max	25	--	3.5						
Bran	Max*	--	--	8	Max*	--	--	8	47	12
	Min*	--	--	0.5	Min*	--	--	0.5		
By-products	Min	--	--	1.5	Max	--	--	8	48	13
Total products	Max	25	--	1.5	Min	21	--	0.5	40_F	--

* Depend on the use of bran.

Table 78. (Continued).

II. Fat Content %		Preferred				Unpreferred				
		Moisture %	Temperature F°	Time hrs		Moisture %	Temperature F°	Time hrs	Table	Figure
Coarse grits	Min	--	--	1.5	Max	--	--	8	40_I,49	14
Medium grits	Min	--	--	1.5	Max	--	--	8	50	15
Meal	Min	21	--	3.5	Max	25	--	1.5	40_H	--
	or	--	70	--	or	--	150	--	51	16
Flour	Min	17	--	--	Max	21	--	--	52	17
Shorts	Min	17	--	1.5	Max	17	--	3.5	40_G	--
Bran	Min	--	--	0.5	Max	--	--	8	53	18
III. Total Oil gram (= Yield gram x fat %)										
Coarse grits	Min	--	110	3.5	Max	--	150	3.5	42_A	--
Medium grits	Min	--	--	1.5	Max	--	--	8	54	19
Major grits	Min	--	--	1.5	Max	--	--	8	55	20
Fine grits	Min	17	--	--	Max	25	--	--	57	22
	or	--	--	1.5	or	--	--	8	56	21
Meal	Min	25	--	--	Max	17	--	--	59	24
	or	--	--	0.5	or	--	--	8	58	23
Flour	Min	17	--	--	Max	21	--	--	60	25
Premium products	Min	--	--	1.5	Max	--	--	8	61	26
Shorts	Min	17	--	1.5	Max	17	--	0.5	40_J	--
Germ	Max	--	--	3.5	Min	--	--	1.5	62	27
Bran	Min	17	150	--	Max	25	150	--	39	--
	or	--	--	0.5	or	--	--	8	63	--

Table 78. (Continued).

IV. Fiber %		Preferred				Unpreferred				
		Moisture %	Temperature F°	Time hrs		Moisture %	Temperature F°	Time hrs	Table	Figure
Coarse grits	Min	21	--	--	Max	17	--	--	64	--
	or	--	150	--	or	--	110	--		
	or	--	--	3.5	or	--	--	8		
Medium grits	Min	25	--	3.5	Max	25	--	8	43_A	--
	or	25	70°	--	or	17	70	--	43_B	--
	or	17	150	--					43_B	
Fine grits	Min	17	--	--	Max	25	--	--	66	30
	or	--	--	1.5	or	--	--	3.5	65	29
Germ	Min	--	--	8	Max	--	--	1.5	67	31
Bran	Max	--	--	0.5	Min	--	--	8	68	32
V. Tannin % of 1 gram Sample										
Coarse grits	Min	17, 21	--	--	Max	25	--	--	70	34
	or	--	--	0.5,1.5, 3.5		--	--	8	69	33

Table 78. (Continued).

VI. Protein %		Preferred				Unpreferred				
		Moisture %	Temperature F°	Time hrs		Moisture %	Temperature F°	Time hrs	Table	Figure
Coarse grits	Max	17	--	0.5	Min	25	--	3.5	40_A	--
Medium grits	Max	--	--	1.5	Min	--	--	8	71	35
Flour	Max	--	--	1.5	Min	--	--	3.5	72	36
Bran	Min	--	--	0.5	Max	--	--	8	73	37
	or	21	--	--		25	--	--	74	38
VII. Agtron Color Reading										
Coarse grits	Max	--	--	8	Min	--	--	0.5	75	39
Fine grits	Max	--	--	8	Min	--	--	1.5	76	40
Flour	Max	25	--	--	Min	21	--	--	77	41

GENERAL CONCLUSIONS

The author summarized the common results from the preceding statements:

1. In Table 78, tempering time appeared most frequently and tempering moisture next, grain temperature appeared most rarely. Therefore, it is reasonable to say that the most important variable is tempering time and second tempering moisture. The least significant is grain temperature.

2. The low tempering moisture, 17%, 21%, and the coldest grain temperature, 70°F along with the short tempering time, 0.5 hr., 1.5 hrs. had the benefits as follows:

   (1) Improved yields
   (2) Decreased fat content
   (3) Decreased amount of total oil
   (4) Decreased tannin content
   (5) Increased protein content

3. The high tempering moisture, 25% and the hot grain temperature, 150°F along with the long tempering time, 3.5 hrs., 8 hrs., had the benefits as follows:

   (1) Decreased the fiber content
   (2) Improved agtron color

Among 36 different combinations of moisture, temperature, and time, this work indicates the optimum conditioning treatment is 17% M, 70°F, 1.5 hrs. Check table 16 for further confirmation. This treatment not only optimized product quality and yield, but also exhibited similicity which reduces the processing cost (adding water, heating, and drying grain etc).

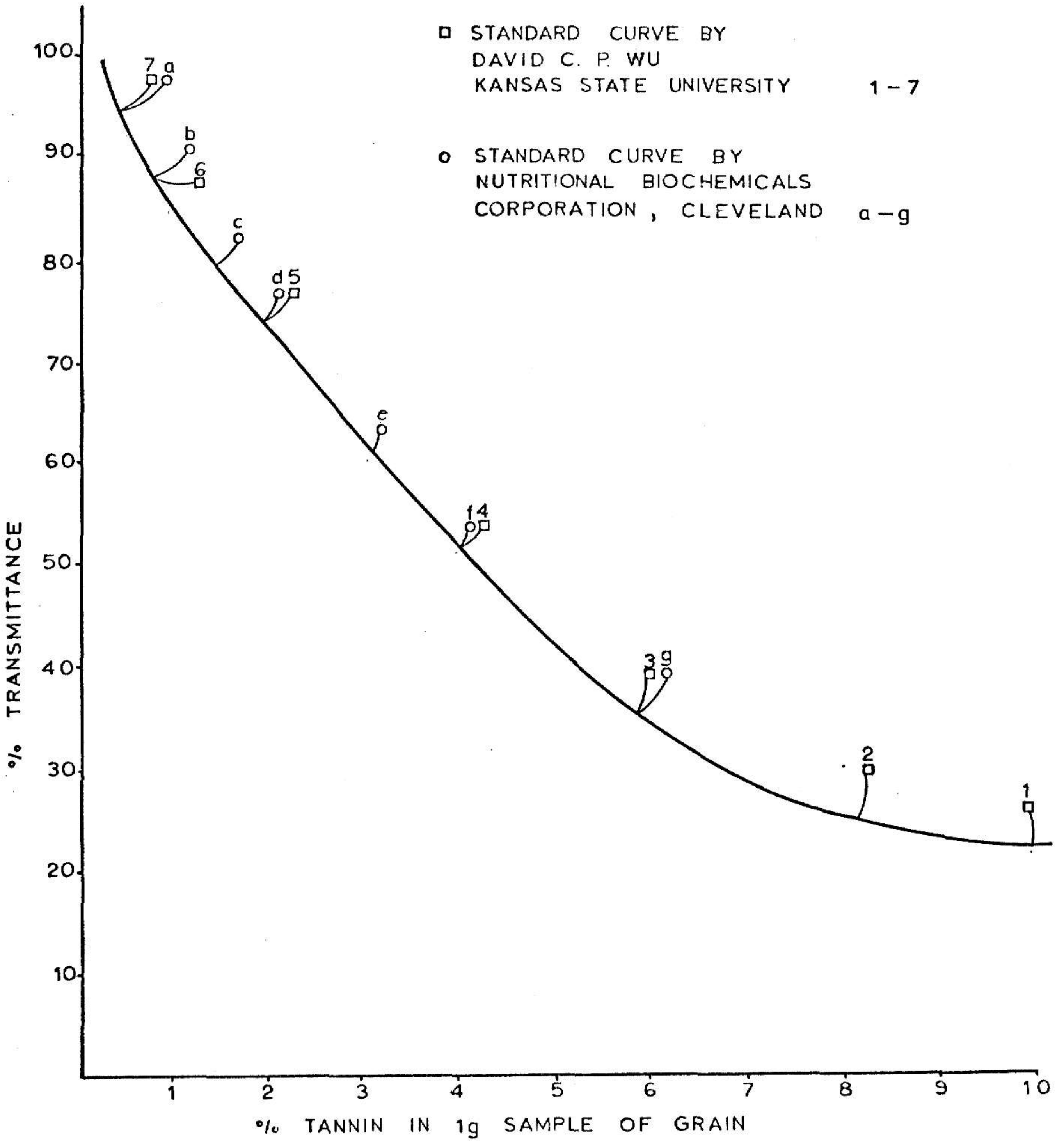

FIG. 1 COLORIMETER READINGS OBTAINED FOR CATECHIN CONCENTRATIONS USING CATECHIN FROM TWO SOURCES AND EQUIVALENT "TANNIN CONTENT" FOR 1gm SAMPLE OF GRAIN EXTRACTED WITH 50ml SOLVENT.

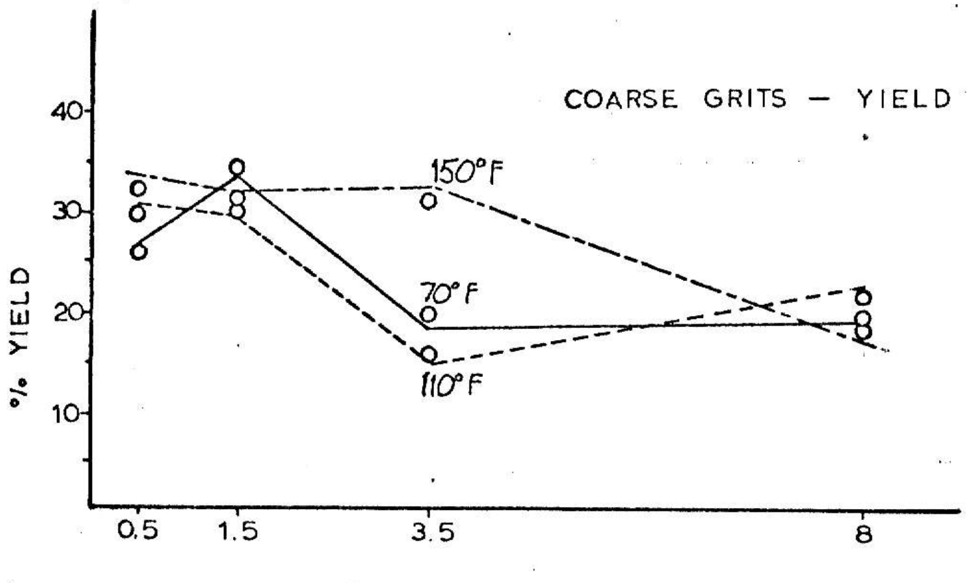

FIG. 2. EFFECT OF TEMPERING TIME ON PERCENT YIELD OF COARSE GRITS.

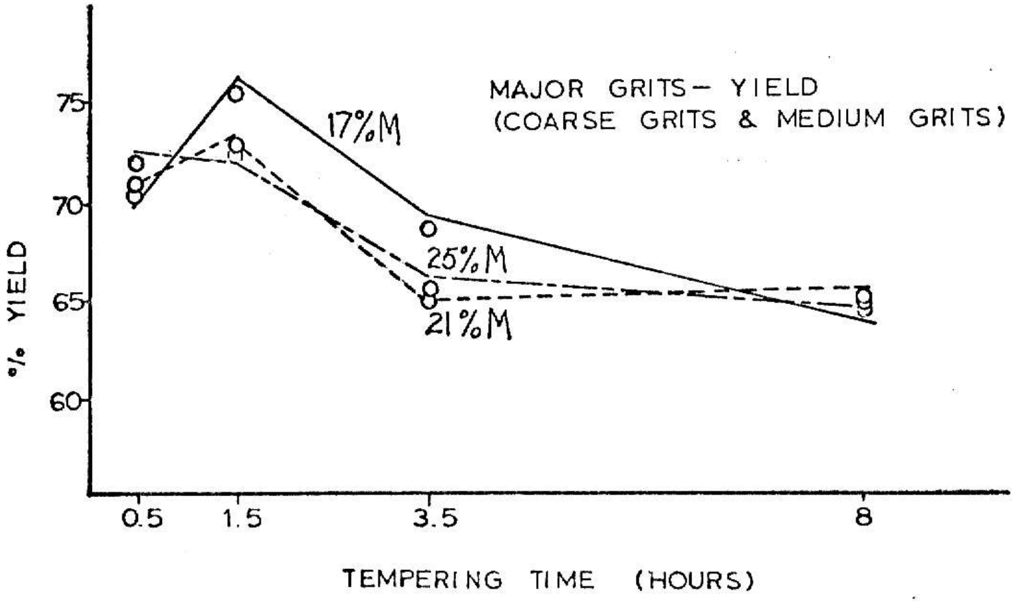

FIG. 3. EFFECT OF TEMPERING TIME ON PERCENT YIELD OF MAJOR GRITS.

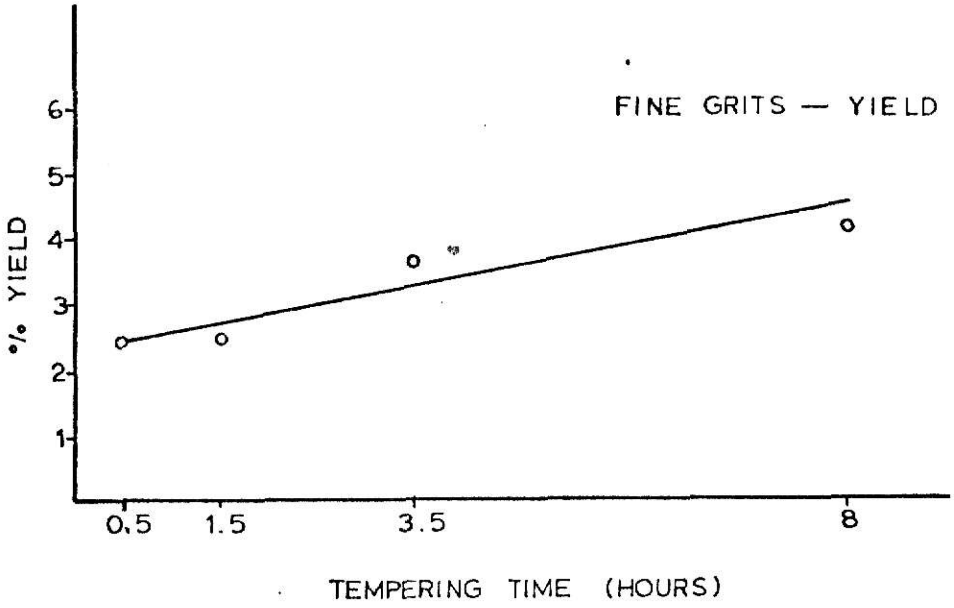

FIG. 4. EFFECT OF TEMPERING TIME ON PERCENT YIELD OF FINE GRITS.

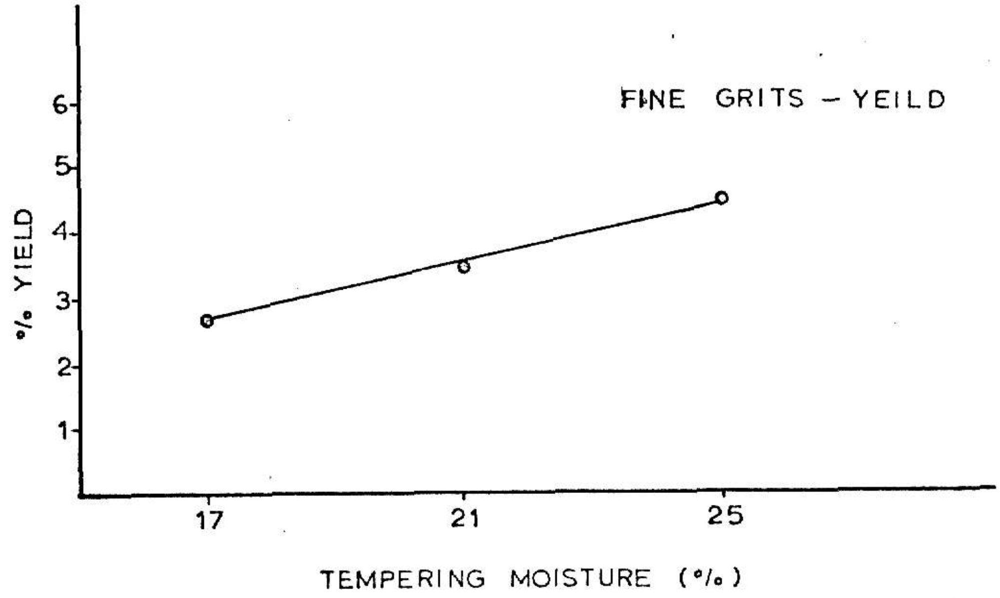

FIG. 5. EFFECT OF TEMPERING MOISTURE ON PERCENT YIELD OF FINE GRITS.

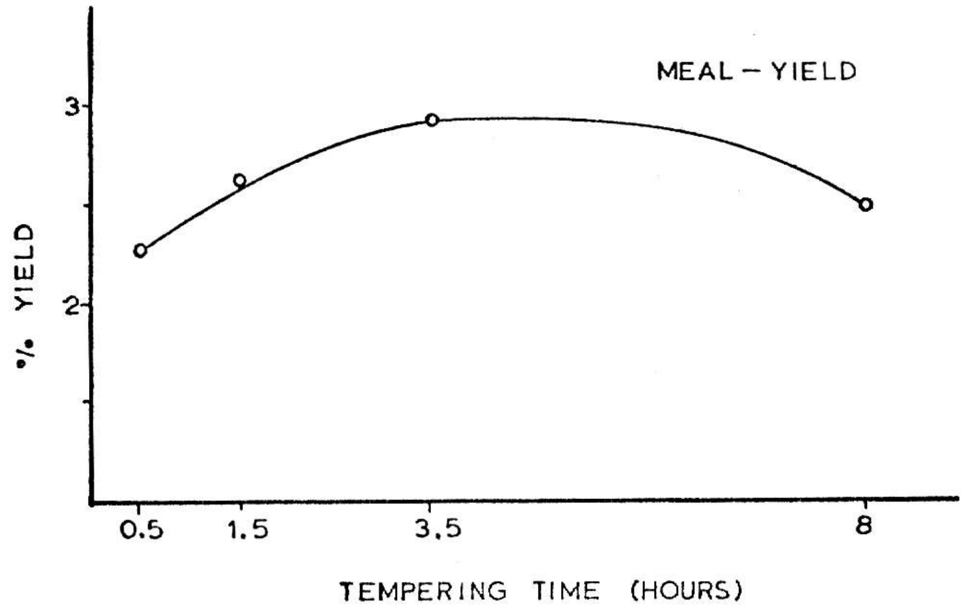

FIG. 6. EFFECT OF TEMPERING TIME ON PERCENT YIELD OF MEAL.

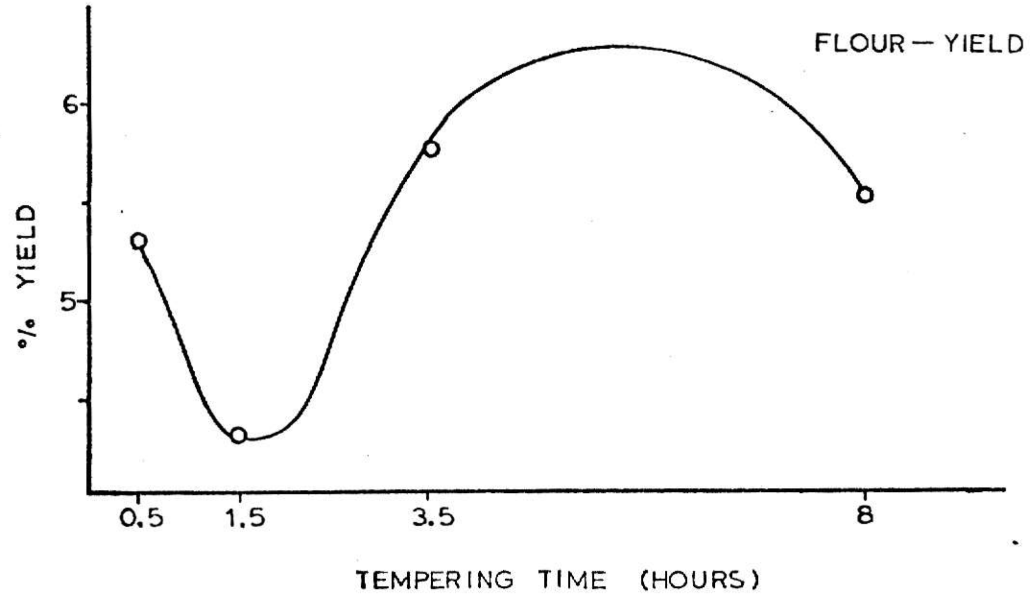

FIG. 7. EFFECT OF TEMPERING TIME ON PERCENT YIELD OF FLOUR.

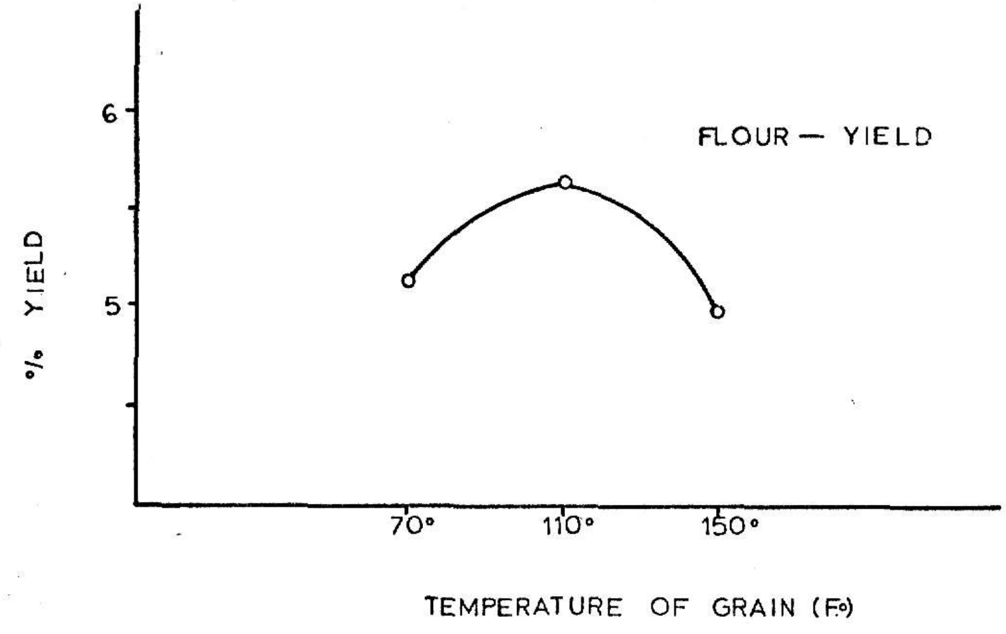

FIG. 8 EFFECT OF TEMPERATURE OF GRAIN ON PERCENT YIELD OF FLOUR.

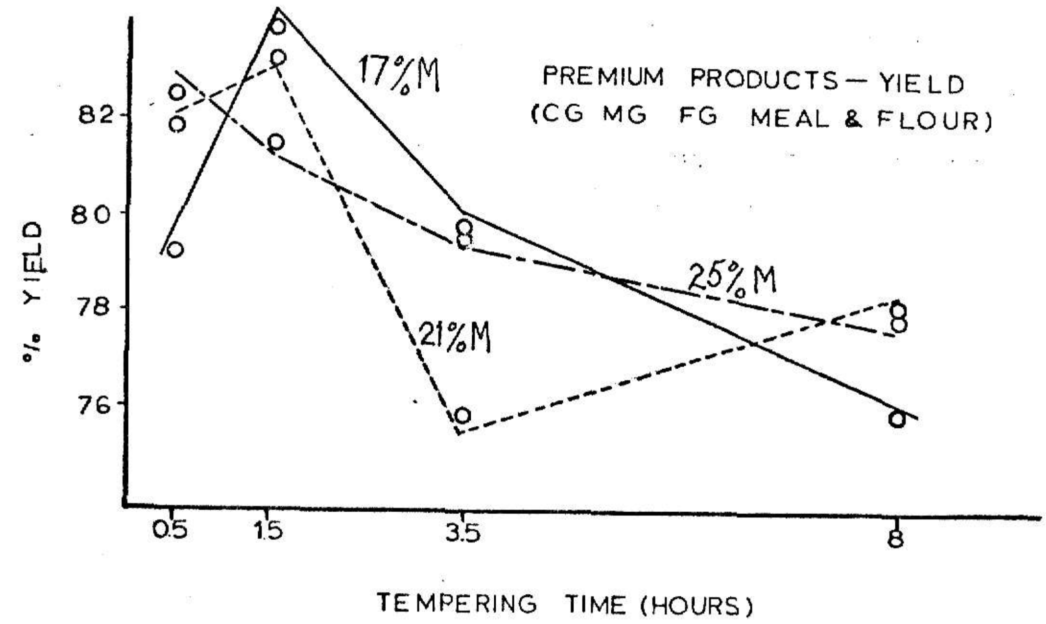

FIG. 9 EFFECT OF TEMPERING TIME ON PERCENT YIELD OF PREMIUM PRODUCTS.

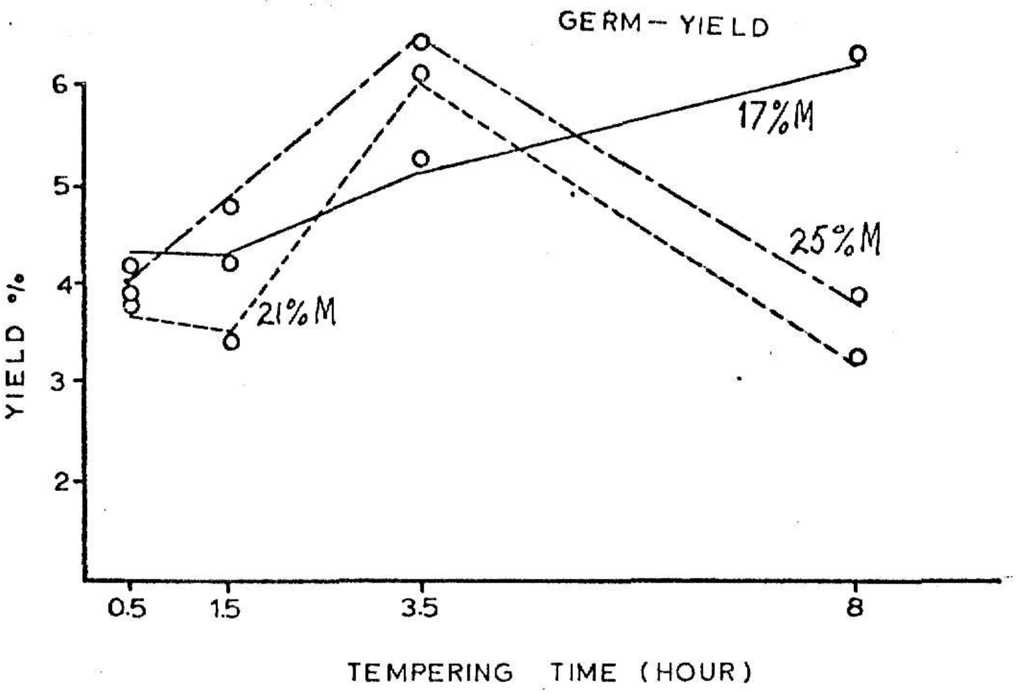

FIG. 10 EFFECT OF TEMPERING TIME ON PERCENT YIELD OF GERM.

SEE FIG. 27 TOTAL OIL GM IN GERM.

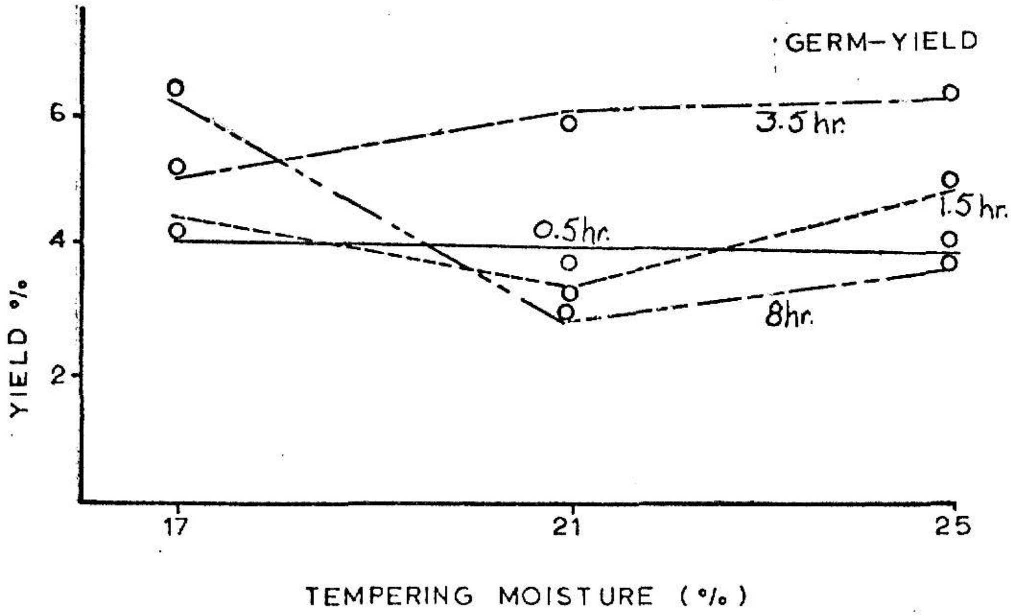

FIG. 11 EFFECT OF TEMPERING MOISTURE ON PERCENT YIELD OF GERM.

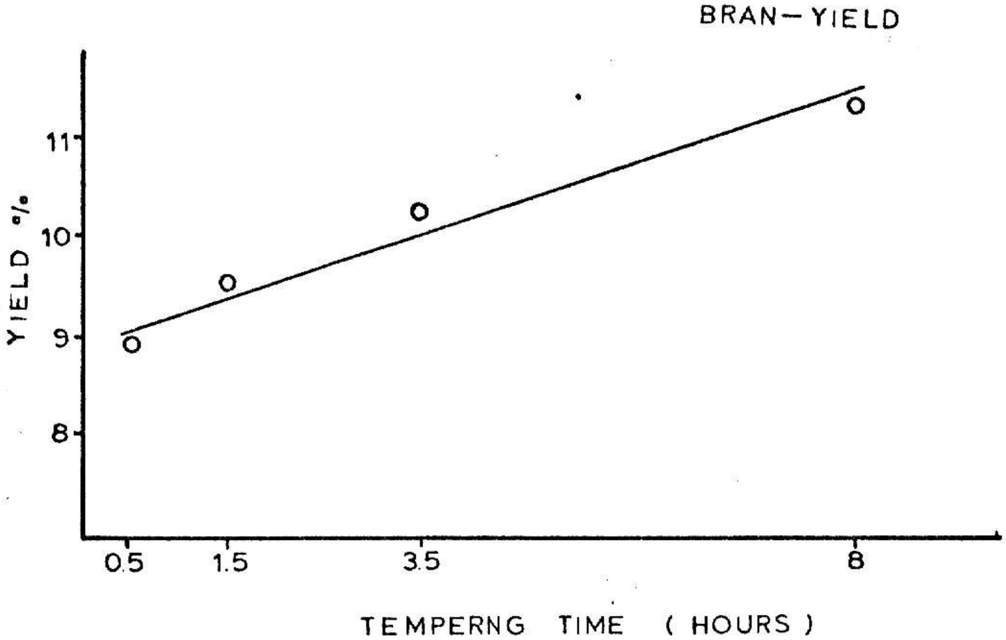

FIG. 12 EFFECT OF TEMPERING TIME ON PERCENT YIELD OF BRAN.

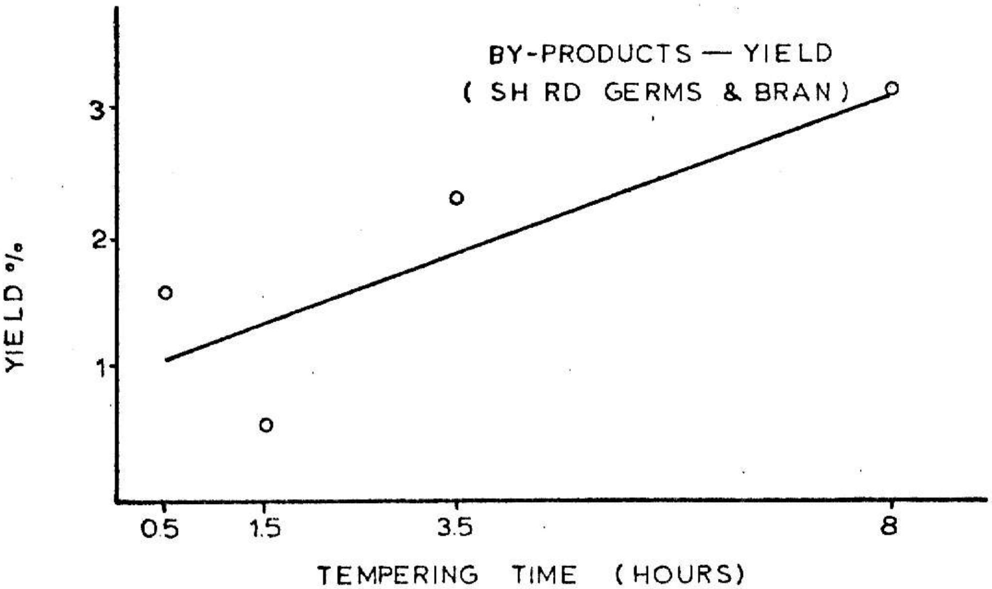

FIG. 13 EFFECT OF TEMPERING TIME OF PERCENT YIELD OF BY-PRODUTS.

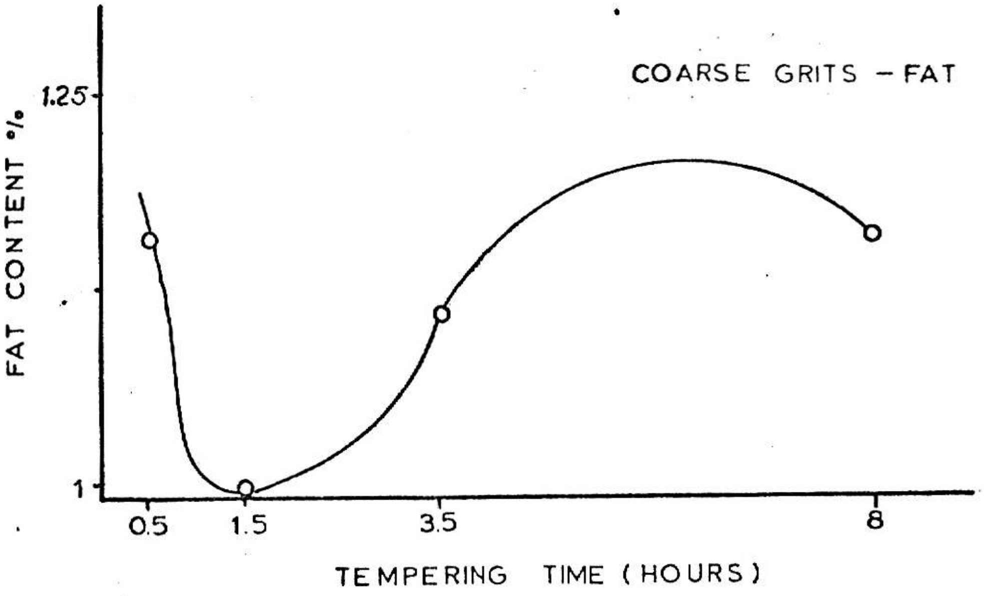

FIG. 14 EFFECT OF TEMPERING TIME ON FAT CONTENT OF COARSE GRITS.

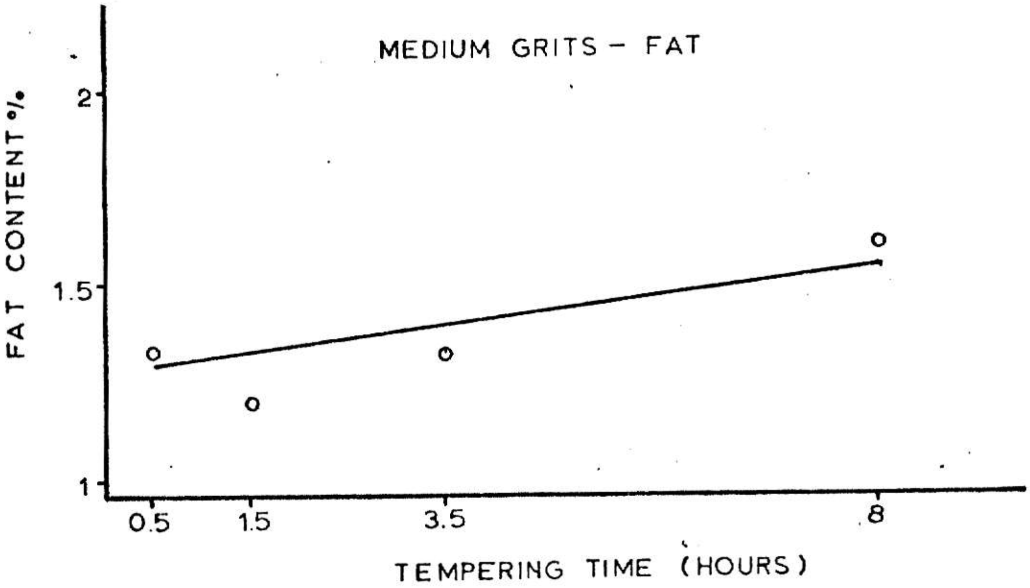

FIG. 15 EFFECT OF TEMPERING TIME ON FAT CONTENT OF MEDIUM GRITS.

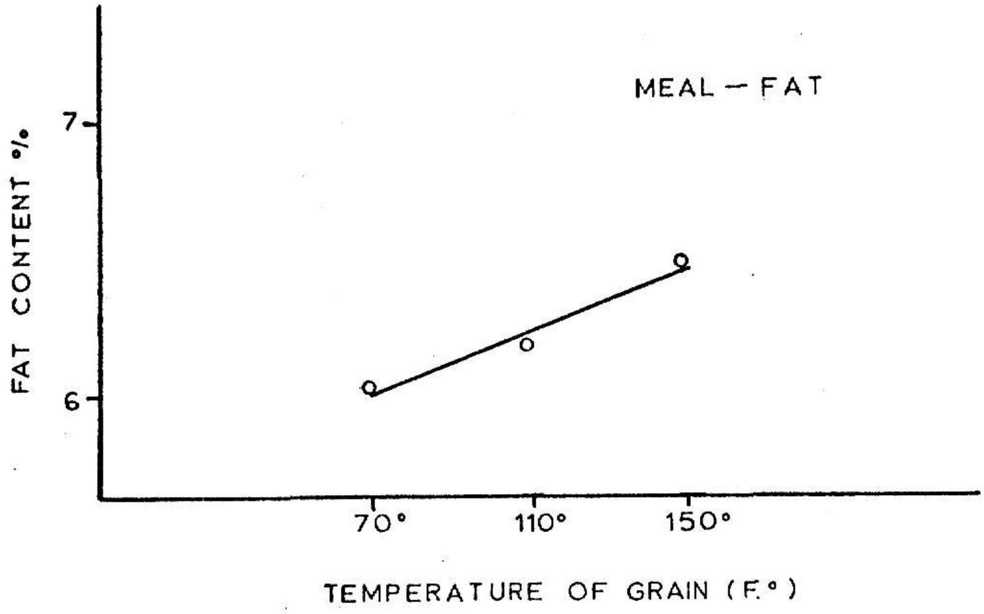

FIG. 16 EFFECT OF TEMPERATURE OF GRAIN ON FAT CONTENT OF MEAL.

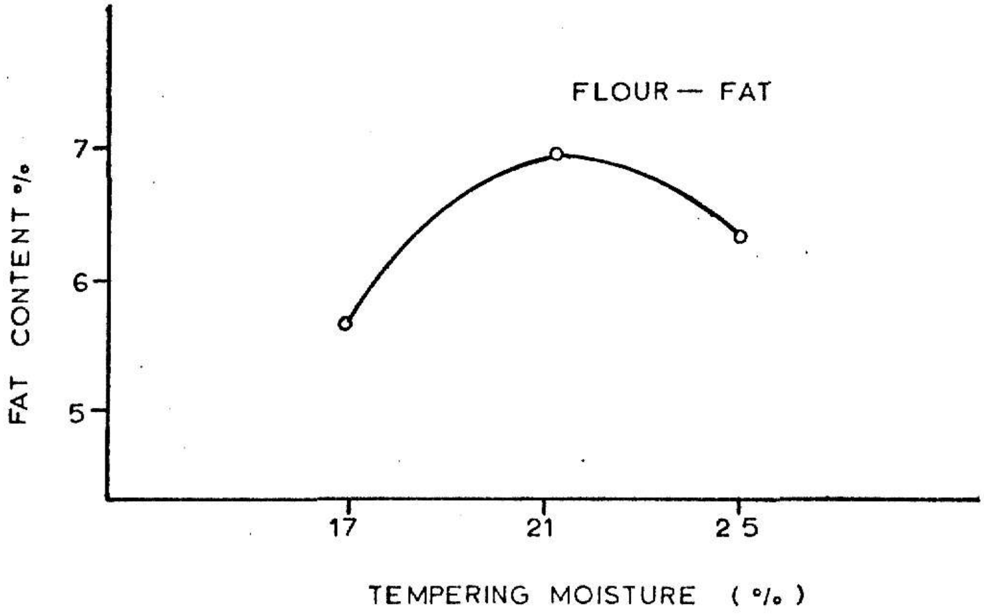

FIG. 17 EFFECT OF TEMPERING MOISTURE ON FAT CONTENT OF FLOUR.

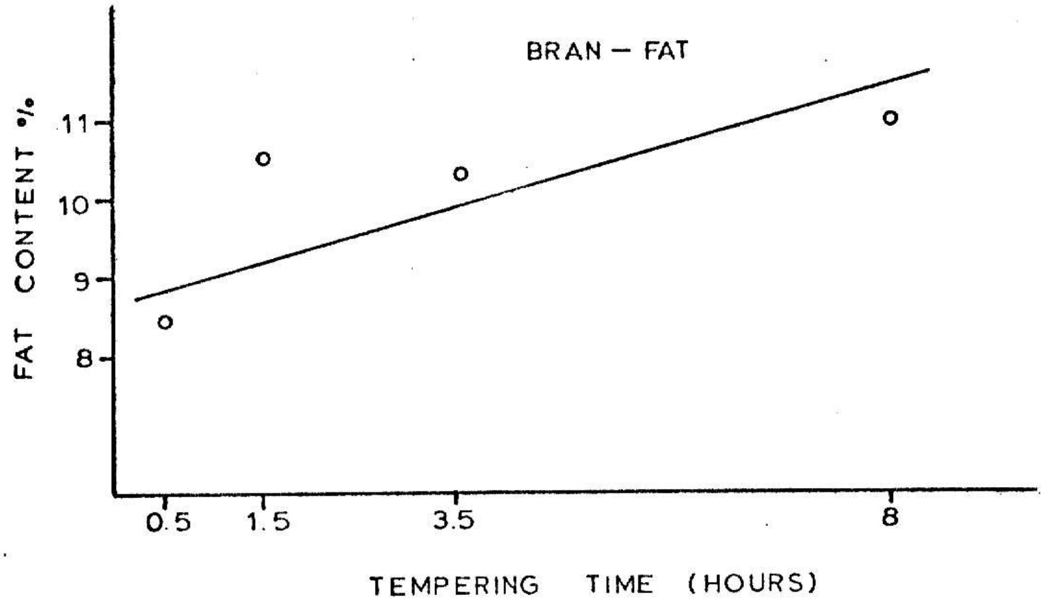

FIG. 18 EFFECT OF TEMPERING TIME ON FAT CONTENT OF BRAN.

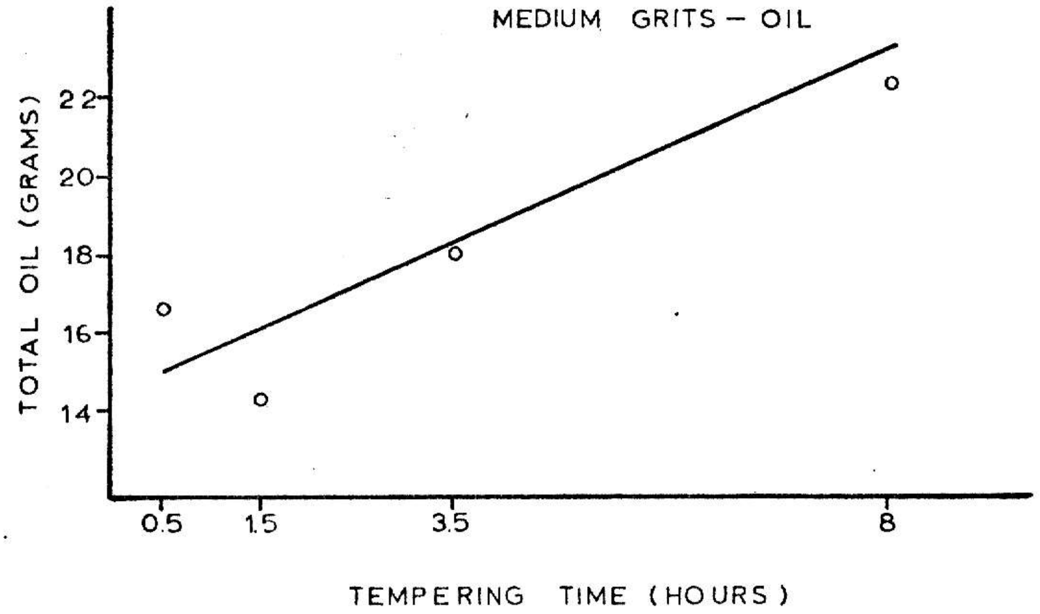

FIG. 19 EFFECT OF TEMPERING TIME ON TOTAL OIL OF MEDIUM GRITS.

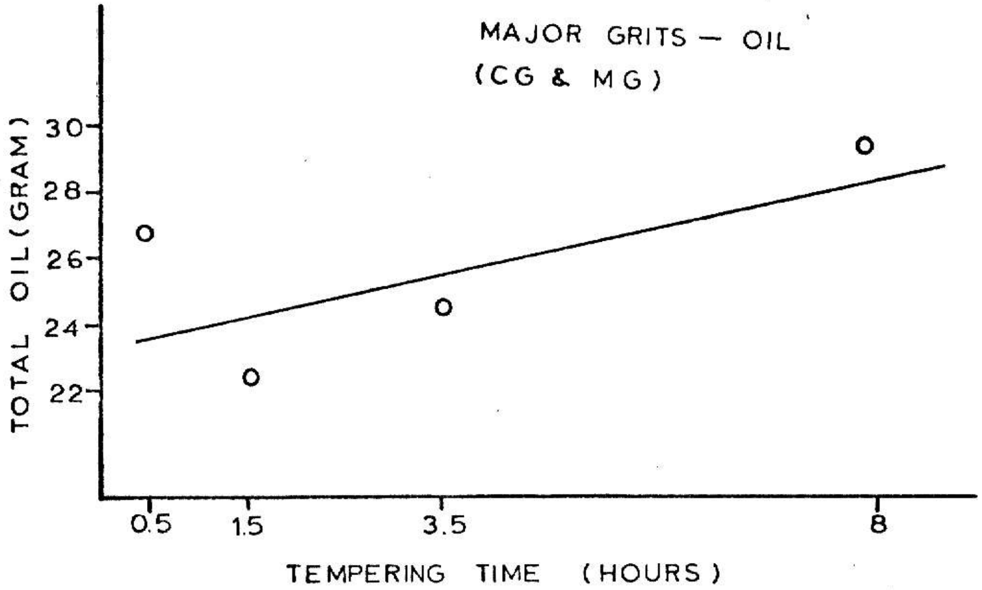

FIG. 20 EFFECT OF TEMPERING TIME OF TOTAL OIL ON MAJOR GRITS.

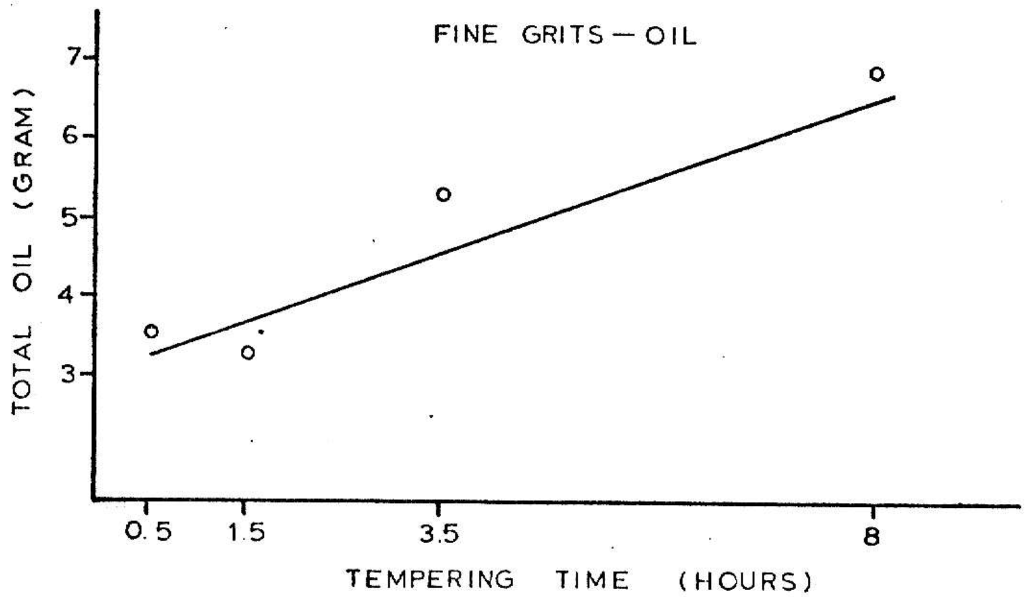

FIG. 21 EFFECT OF TEMPERING TIME ON TOTAL OIL ON FINE GRITS.

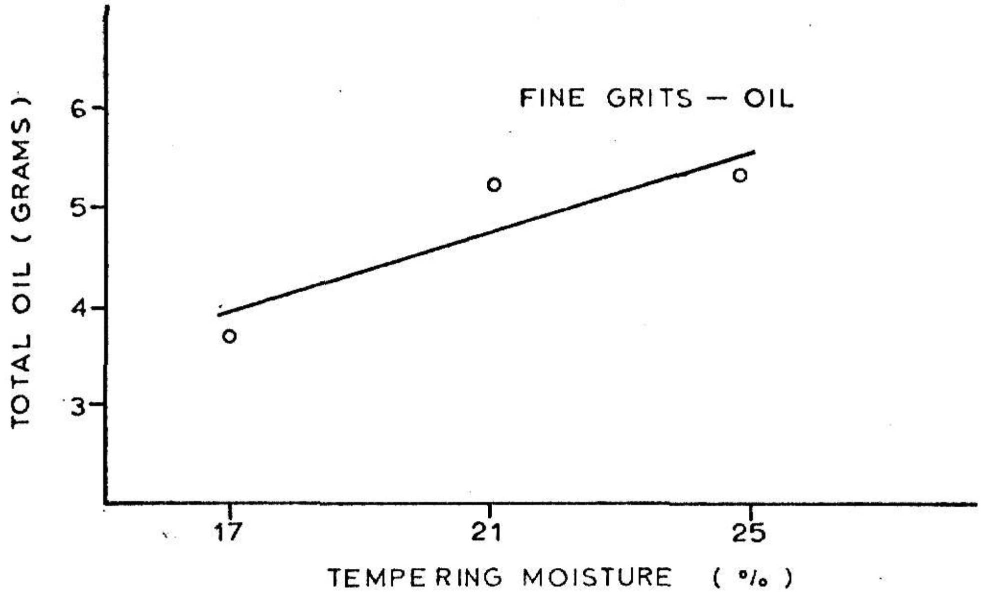

FIG. 22 EFFECT OF TEMPERING MOISTURE ON TOTAL OIL OF FINE GRITS.

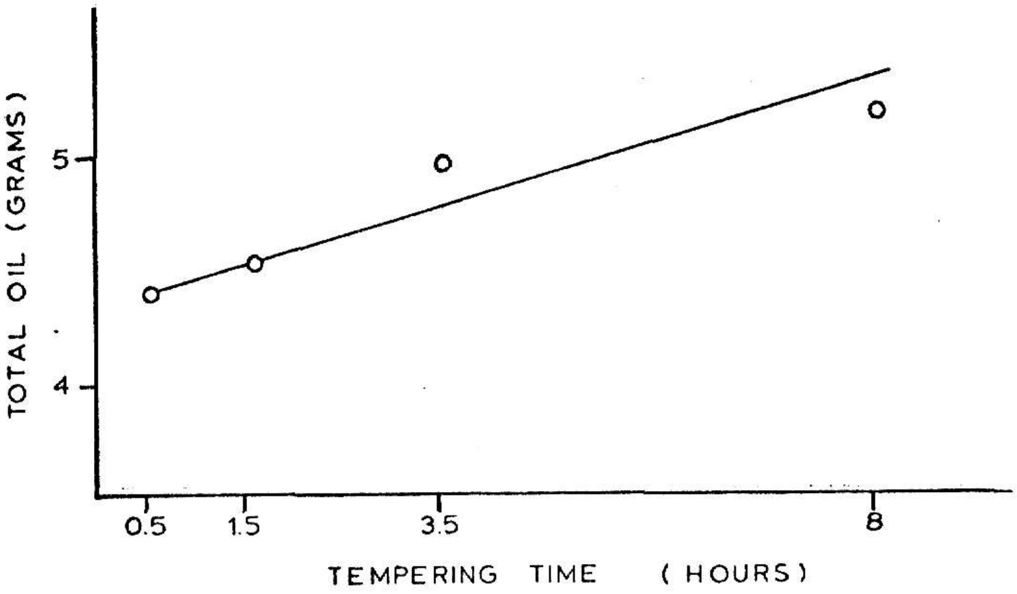

FIG. 23 EFFECT OF TEMPERING TIME ON TOTAL OIL OF MEAL.

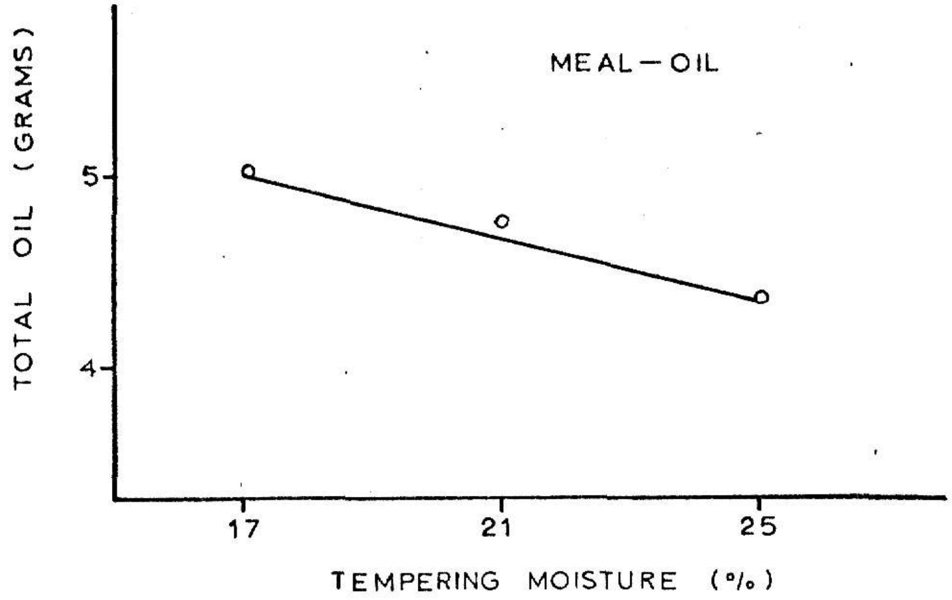

FIG. 24 EFFECT OF TEMPERING MOISTURE ON TOTAL OIL OF MEAL.

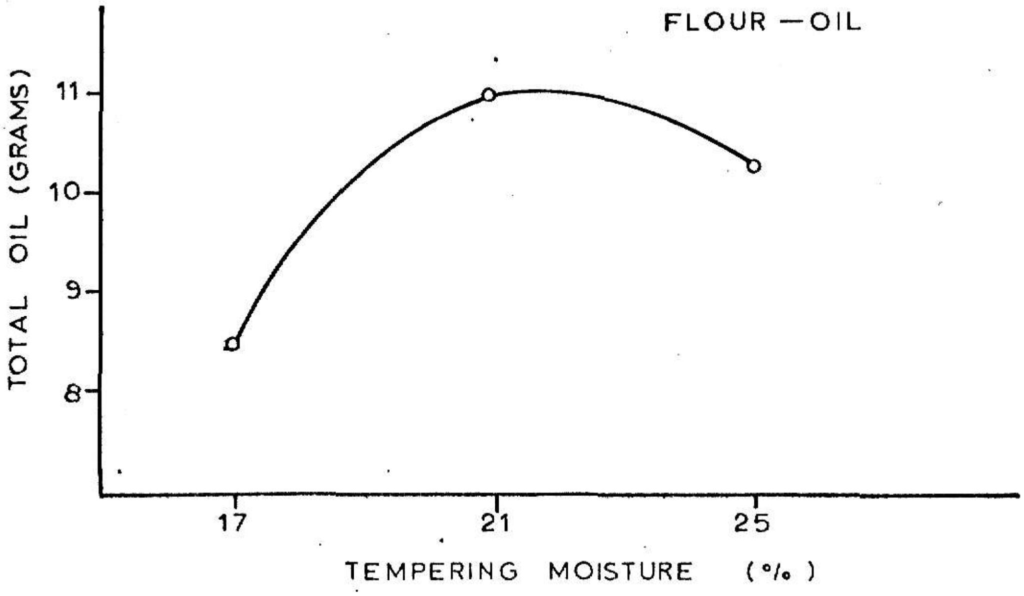

FIG. 25 EFFECT OF TEMPERING MOISTURE ON TOTAL OIL OF FLOUR.

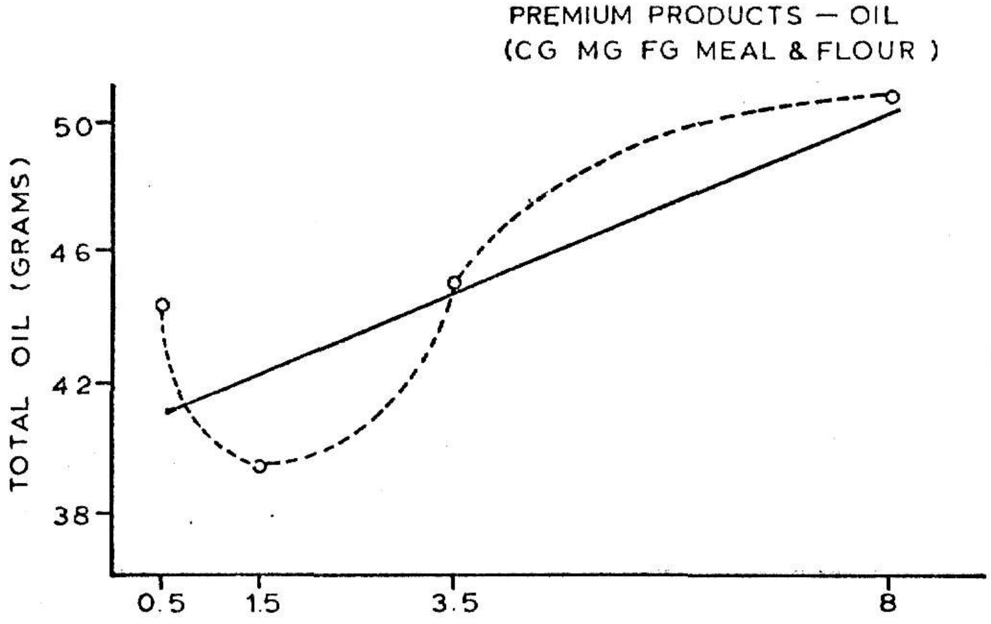

FIG. 26 EFFECT OF TEMPERING TIME ON TOTAL OIL OF PREMIUM PRODUCTS.

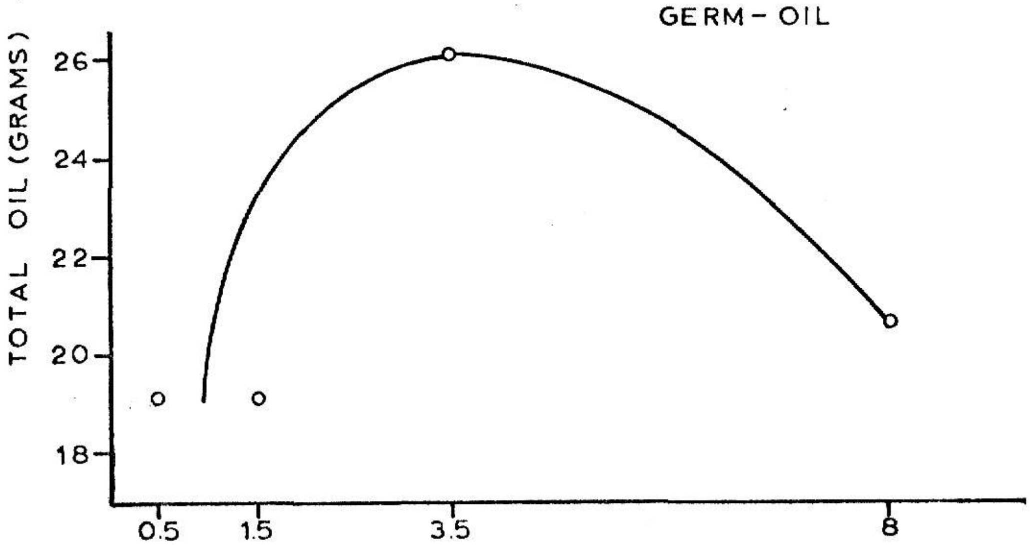

FIG. 27 EFFECT OF TEMPERING TIME ON TOTAL OIL OF GERM.

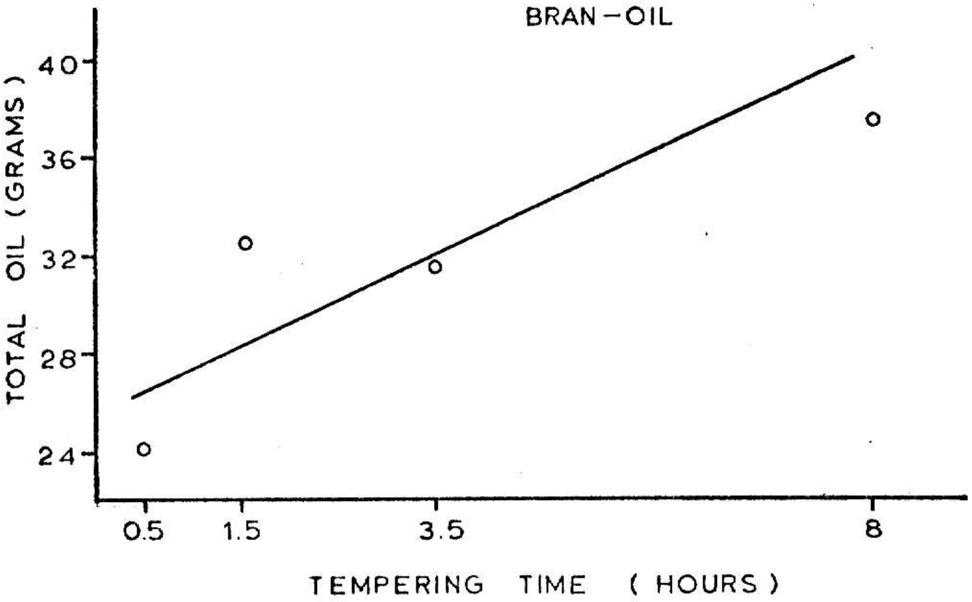

FIG. 28 EFFECT OF TEMPERING TIME ON TOTAL OIL OF BRAN.

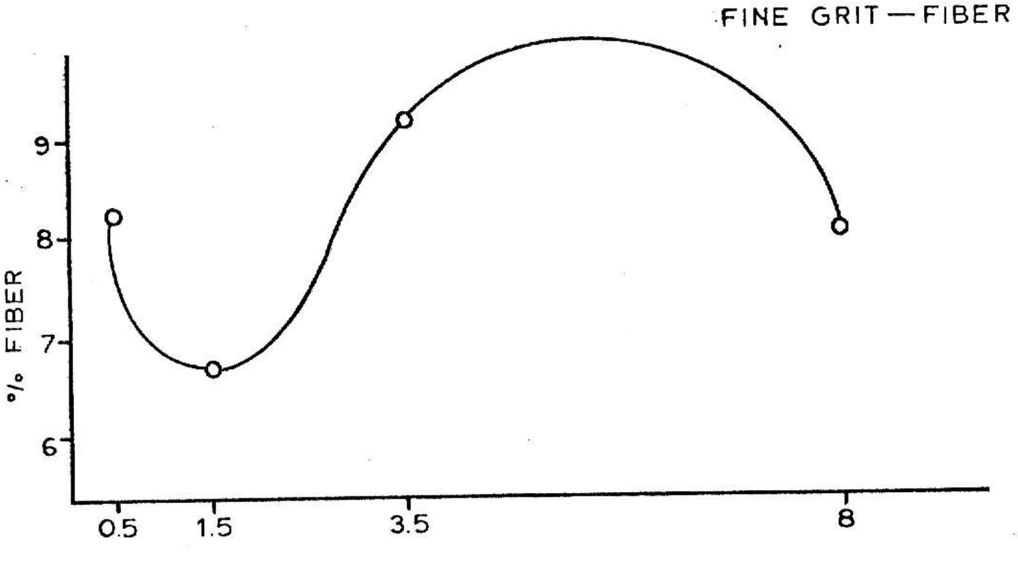

FIG. 29 EFFECT OF TEMPERING TIME ON FIBER CONTENT OF FINE GRITS.

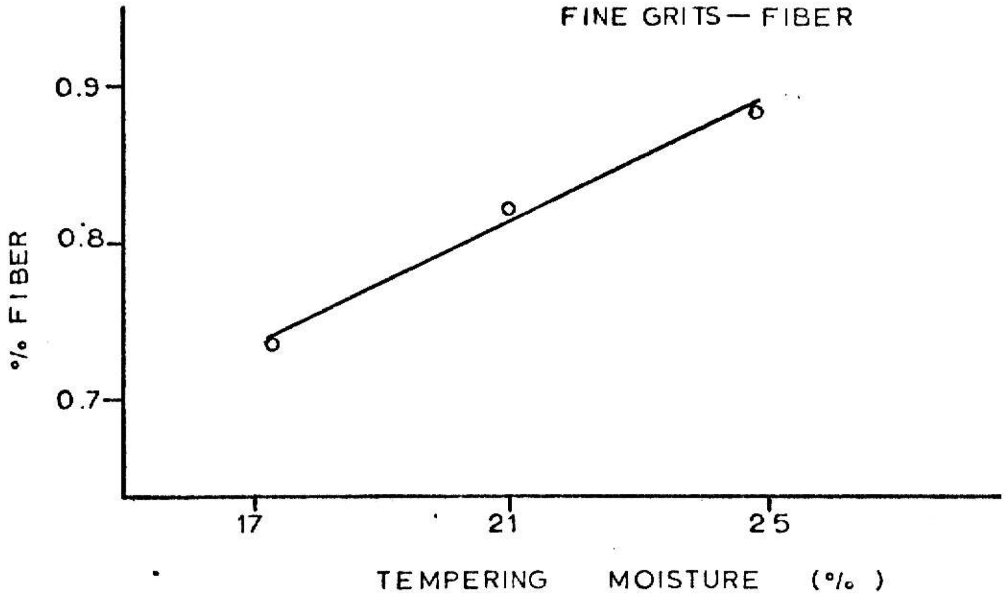

FIG. 30 EFFECT OF TEMPERING MOISTURE ON FIBER CONTENT OF FINE GRITS.

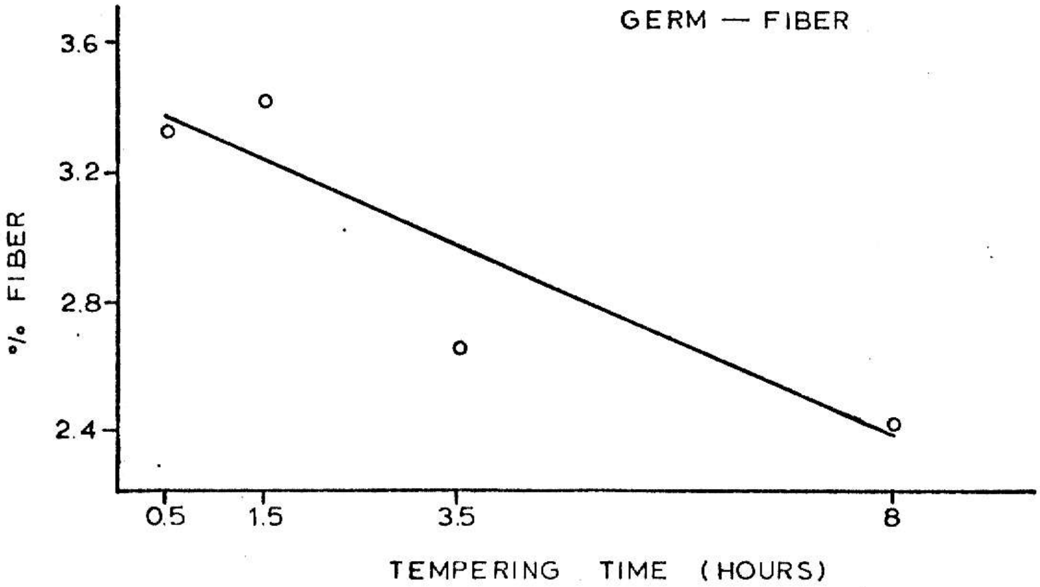

FIG. 31 EFFECT OF TEMPERING TIME ON FIBER CONTENT OF GERM.

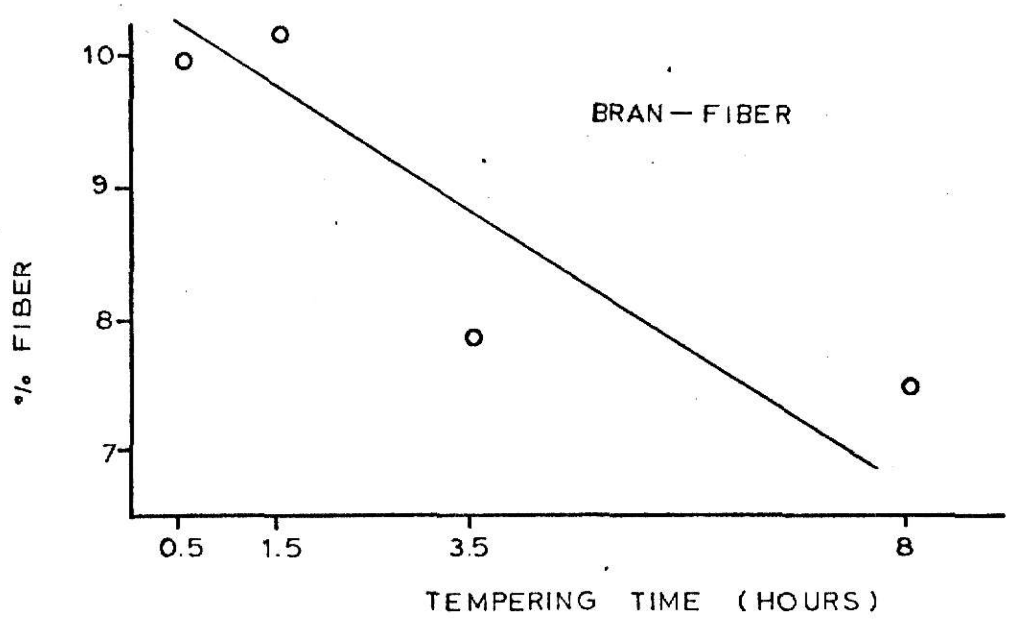

FIG. 32 EFFECT OF TEMPERING TIME ON FIBER CONTENT OF BRAN.

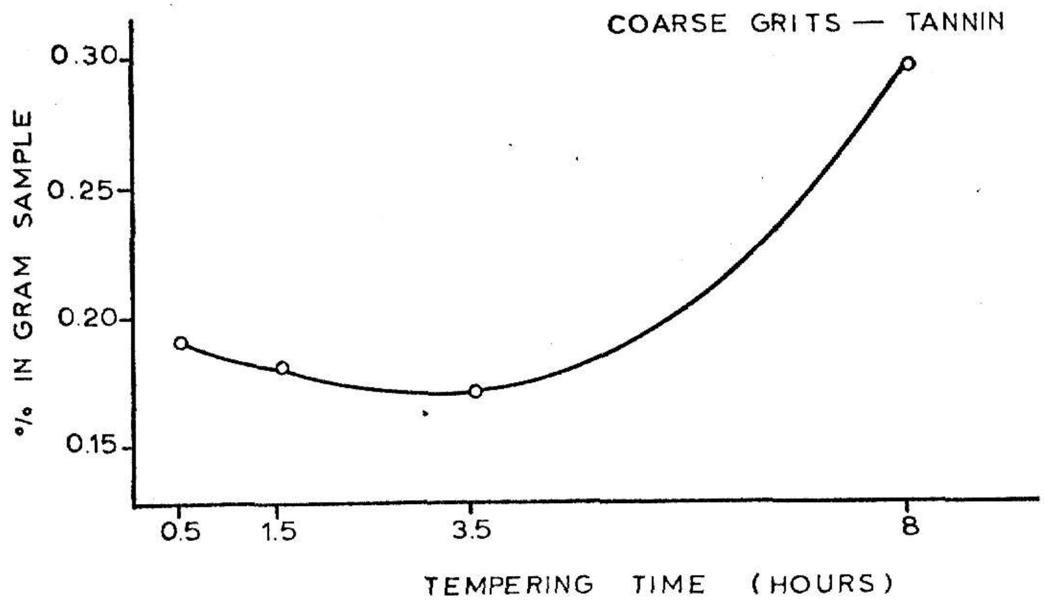

FIG. 33 EFFECT OF TEMPERING TIME ON TANNIN CONTENT OF COARSE GRITS.

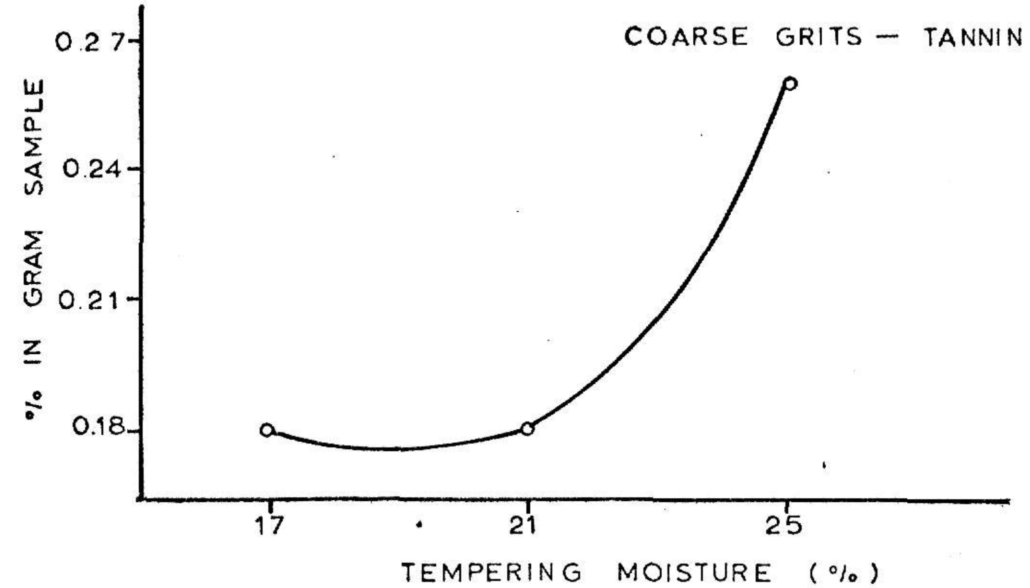

FIG. 34 EFFECT OF TEMPERING MOISTURE ON TANNIN CONTENT OF COARSE GRITS.

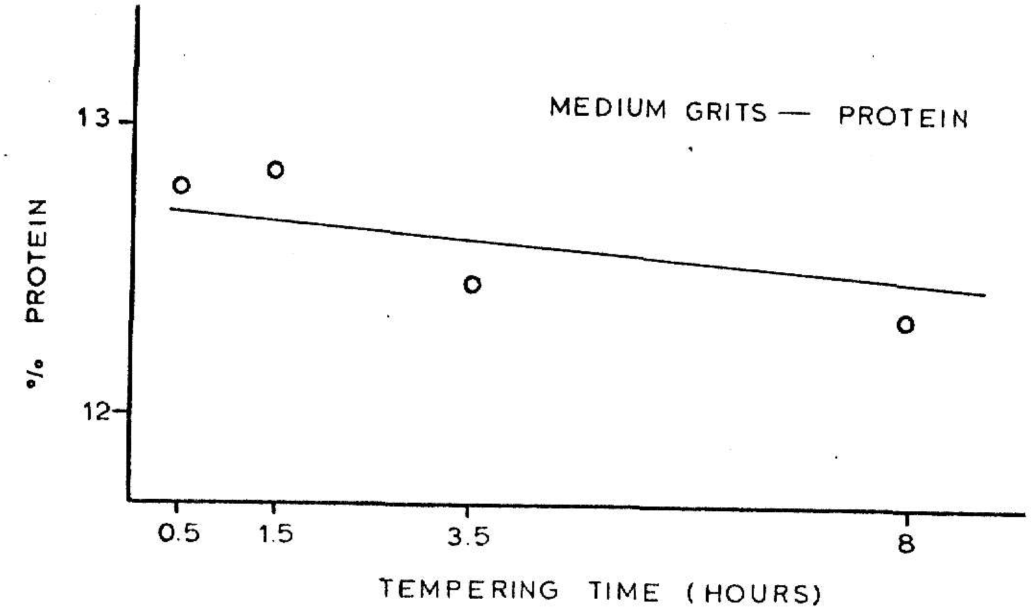

FIG 35 EFFECT OF TEMPERING TIME ON PROTEIN CONTENT OF MEDIUM GRITS.

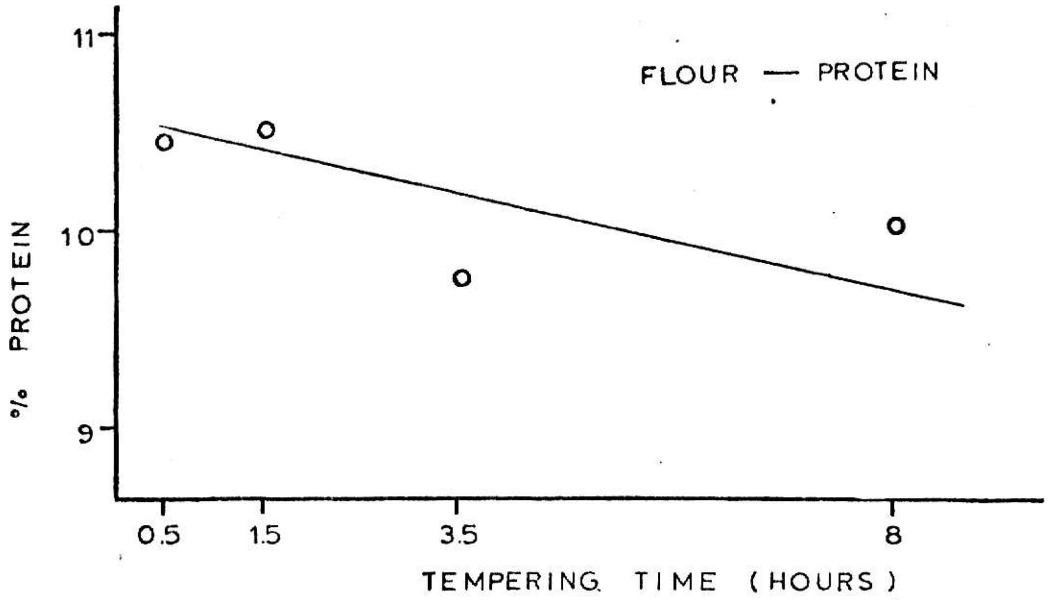

FIG. 36 EFFECT OF TEMPERING TIME ON PROTEIN CONTENT OF FLOUR.

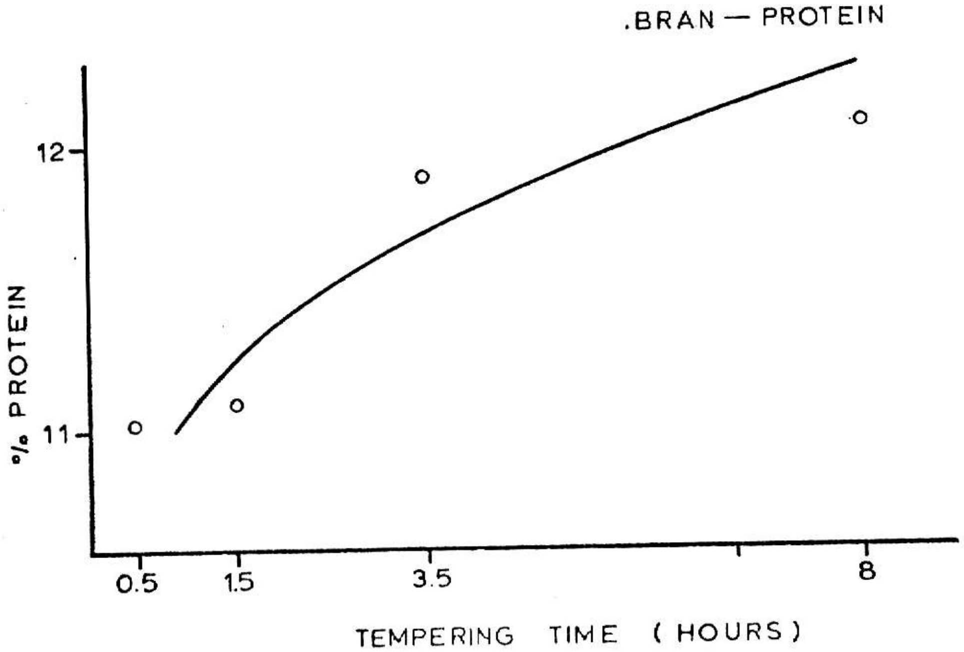

FIG. 37 EFFECT OF TEMPERING TIME ON PROTEIN CONTENT OF BRAN.

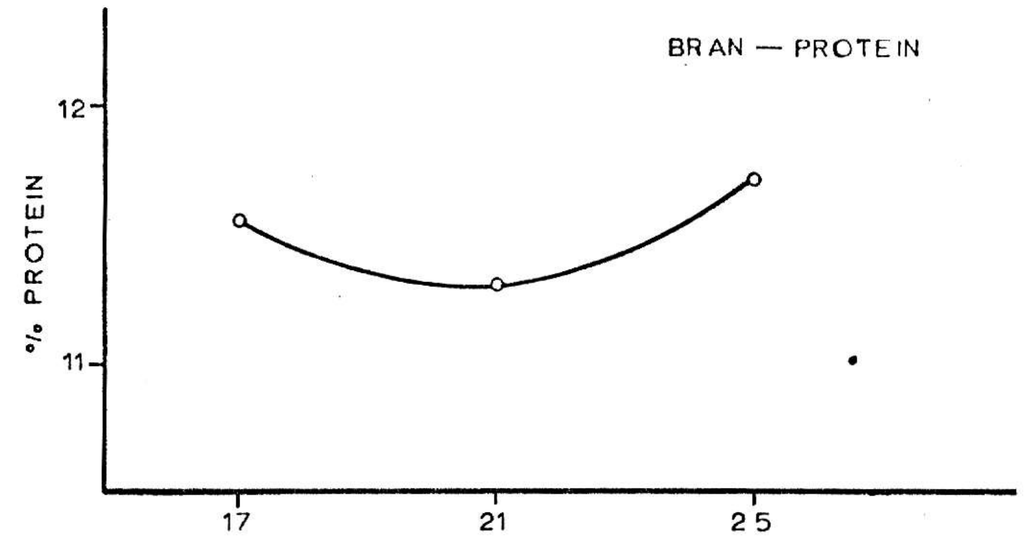

FIG. 38 EFFECT OF TEMPERING MOISTURE ON PROTEIN CONTENT OF BRAN.

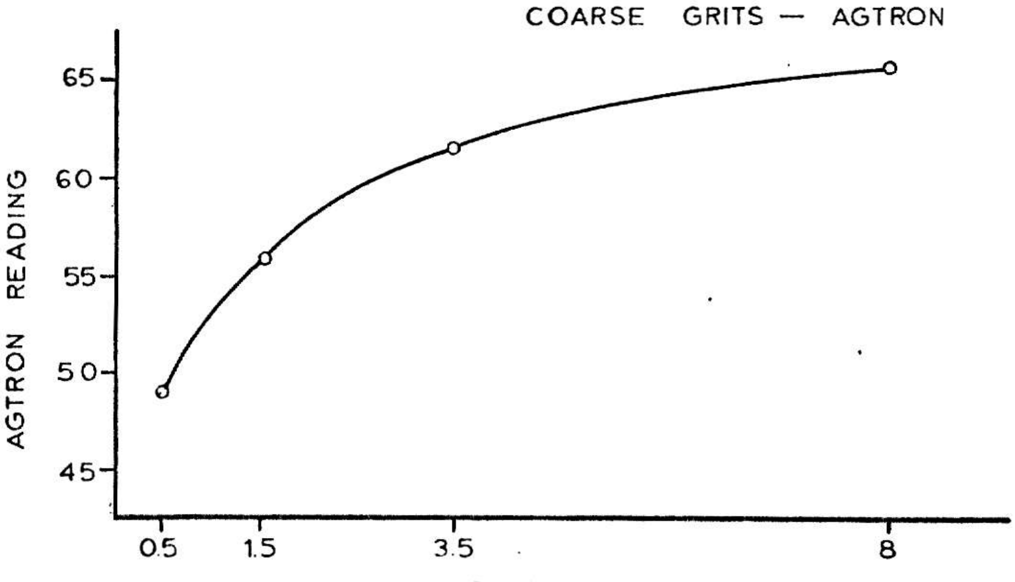

FIG. 39 EFFECT OF TEMPERING TIME ON AGTRON COLOR OF COARSE GRITS.

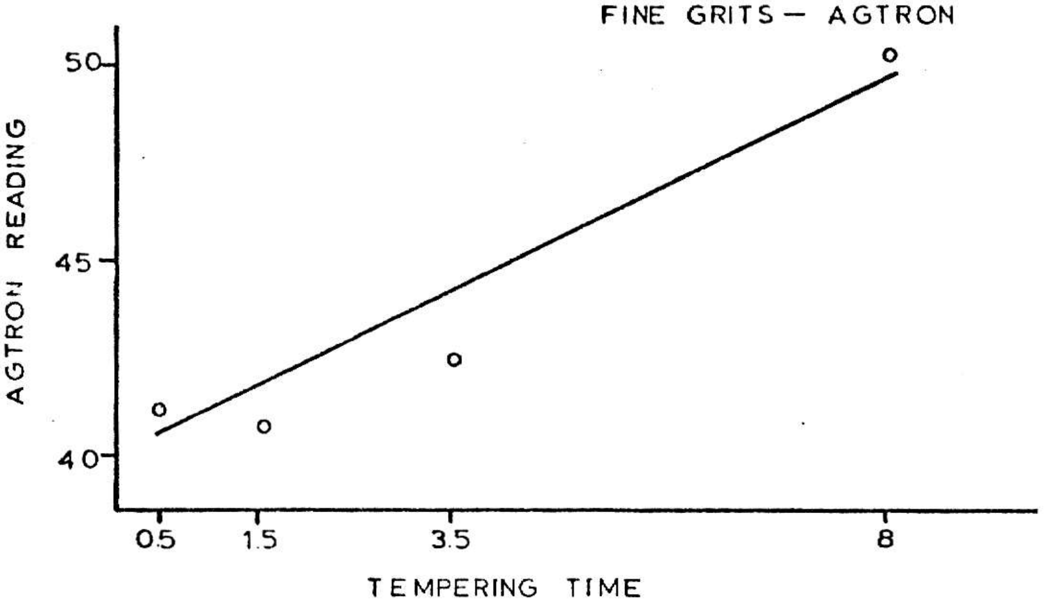

FIG. 40 EFFECT OF TEMPERING TIME ON AGTRON COLOR OF FINE GRITS.

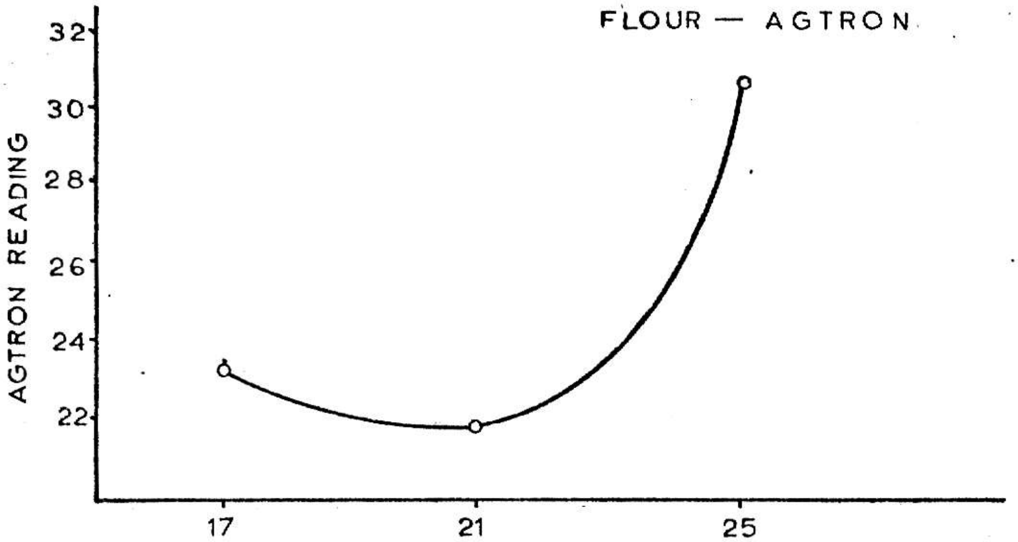

FIG. 41 EFFECT OF TEMPERING MOISTURE ON AGTRON COLOR OF FLOUR.

SUGGESTIONS FOR FUTURE RESEARCH

1. Sorghum grain Dry-Milling: a comparison of several procedures for tempering low-moisture sorghum grain.
   pretempering
   2nd tempering
   pretempering + 2nd tempering
   pretempering + 1st tempering + 2nd tempering
   1st tempering + 2nd tempering
2. Sorghum grain Dry-Milling: the effect of conditioning treatment by adding minimum or zero amount of moisture to grains on the drying operation cost. As energy becomes more and more precious, it is a good practice to have a low level of milling moisture to reduce or even omit the drying operation.
3. Solvent extraction milling (S.E.M.) of sorghum grain. A commercial rice milling plant has been modified to produce good quality rice with high yield of whole kernel and many other new byproducts. S.E.M. of sorghum grain could provide a good field to be explored.
4. The commercial feasibility of magnetic separation of bran to which static charge is added by flowing air in dry-milling of sorghum grain.
5. The relationship between fat content and particle size of sorghum grits. Would it be a direct proportion or indirect?
6. The relationship between starch damage and oil content of the dry-milling of sorghum grain's product and the speed of impace mill.

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The writer is grateful to Merlene Ryan for her valuable assistance with the chemical analyses of the products, and to others members of the Department of Grain Science and Industry, who assisted him during the course of the study.

APPENDIX

Table 79. Tannin content of white and brown sorghum grains.

Fractions	Symbol	Spectro- photometer Reading	Tannin % in 2 gram	Tannin % in 1 gram	Tannin % in 1 gram 14 M.B.
White Sorghum Grain					
Whole kernel	A	93.8	0.50	0.25	0.237
Coarse grits +14W	B	97.5	0.30	0.15	0.147
Medium grits +24W	C	99.4	0.25	0.13	0.128
Fine grits +34W	D	90.0	0.70	0.35	0.354
Meal +66W	E	96.2	0.40	0.20	0.189
Flour -66W	F	94.0	0.47	0.24	0.235
Shorts	G	91.0	0.67	0.34	0.329
Germ	H	89.0	0.77	0.39	0.369
Reddog -66W	I	84.7	1.05	0.53	0.485
Bran	J	78.3	1.47	0.74	0.695
Brown Sorghum Grain					
Whole kernel	A^1	25.2	2.76	1.38	1.309
Coarse grits +14W	1	79.0	1.45	0.73	0.674
Medium grits +24LW	2	74.5	1.73	0.86	0.829
Fine grits +34W	3	64.2	2.58	1.29	1.204
Meal +66W	4	51.2	3.78	1.89	1.750
Flour -66W	5	60.0	2.95	1.48	1.367
Shorts	6	39.2	5.43	2.72	2.441
Germ	8	18.8	11.35	5.68	5.211
Reddog -66W	7	18.2	11.80	5.90	5.676
Bran	9	2.1	20.00	10.00	9.280

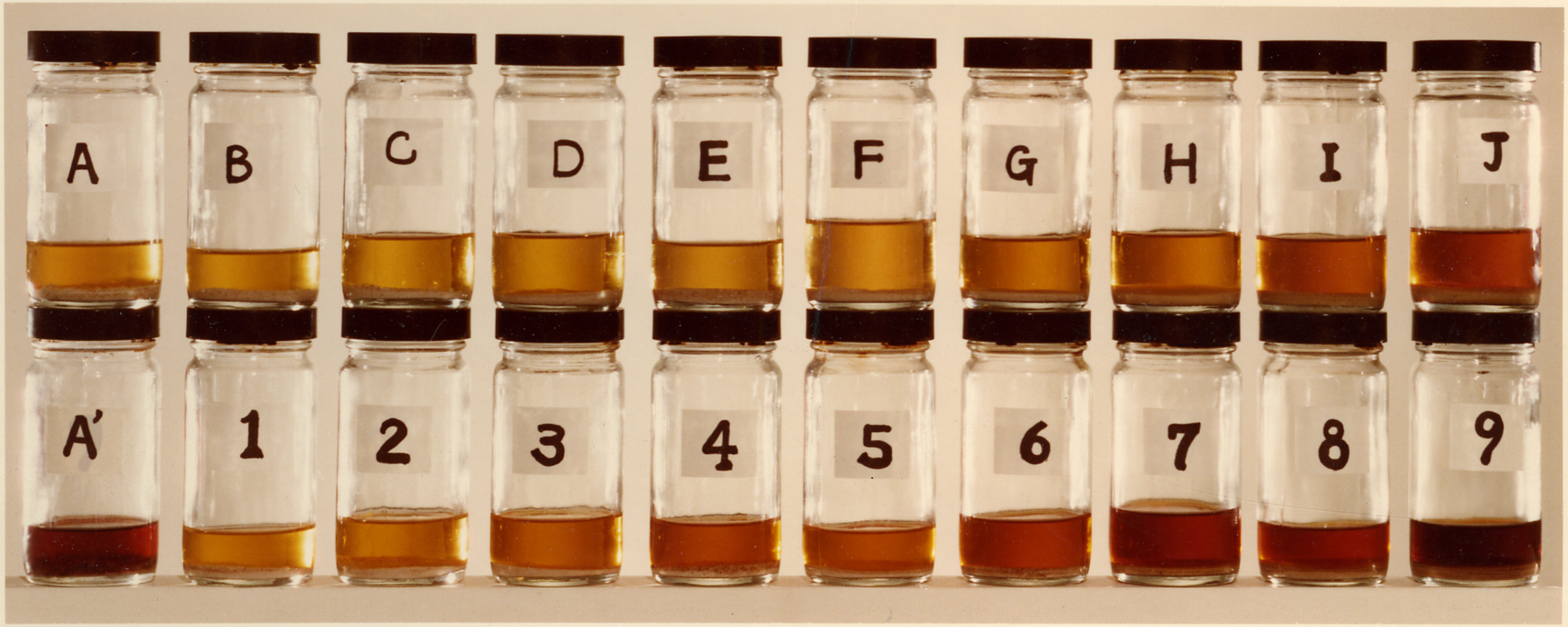
Tannin Extraction of Sorghum Grain's Products by .1% HCl Methanol

White Sorghum Grain

A.	Whole kernel	B.	Coarse grits +14W	C.	Medium grits +24LW	D.	Fine grits +34W	E.	Meal +66W
F.	Flour -66W	G.	Shorts	H.	Germ	I.	Reddog -66W	J.	Bran

Brown Sorghum Grain

A^1.	Whole kernel	1.	Coarse grits +14W	2.	Medium grits +24LW	3.	Fine grits +34W	4.	Meal +66W
5.	Flour -66W	6.	Shorts	7.	Reddog -66W	8.	Germ	9.	Bran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SORGHUM GRAIN DRY-MILLING-
EXPERIMENTS OF COLD, WARM, HOT CONDITIONING

by

DAVID CHUNG PING WU

B.S., National Chung-Hsing University

Taichung, Taiwan 1971

AN ABSTRACT OF A MASTER"S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1976

GENERAL CONCLUSIONS

The author summarized the common results from the preceding statements:

1. The most important variable is the tempering time and second tempering moisture. The least significant is grain temperature.

2. The low tempering moisture, 17%, 21%, and the coldest grain temperature, 70°F along with the short tempering time, 0.5 hr, 1.5 hrs had the benefits as follows:

    (1) Improved yields

    (2) Decreased fat content

    (3) Decreased amount of total oil

    (4) Decreased tannin content

    (5) Increased protein content

3. The high tempering moisture, 25% and the hot grain temperature, 150°F along with the long tempering time, 3.5 hrs, 8 hrs, had the benefits as follows:

    (1) Decreased the fiber content

    (2) Improved agtron color

Amoung 36 different combinations of moisture, temperature, time, this work indicates the optium conditioning treatment is 17% M, 70°F, 1.5 hrs. Check table 16 for further confirmation. This treatment not only optimized product quality and yield, but also exhibited similicity which reduces the processing cost (adding water, heating, and drying grain etc).