EFFECT OF FLOUR PARTICLE SIZE AND EMULSIFIERS ON QUALITY OF CAKES MADE WITH CAKE FLOUR OF VARYING EXTRACTION

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

For many years the art of cake making remained relatively unchanged. More recently, several new types of layer cakes have been introduced with new types of flours and emulsifiers. One of these later cakes is the high ratio type, that uses sugar up to 110 or more parts relative to flour. There has been a great preference in the U.S. for this type of cake. Apart from providing the consumer with a sweeter flavor, such cakes are more tender, softer, and more attractive than low ratio types. Chlorinated special soft wheat flour and shortening containing efficient emulsifiers in these cakes have enabled sugar to be used at a high ratio, thus making a softer and more tender product.

Soft wheat flour quality is one of the most important factors in producing desirable layer cakes. Factors that have been found to influence flour quality include: 1) protein quantity; 2) flour pH (index of chlorination); 3) flour extraction rate and 4) flour granulation. Cake bakers have the general understanding that high ratio cakes should be made from a highly refined soft wheat flour with uniform and small granulation, a low protein content, and bleached and treated with chlorine gas to a range of pH 4.5-4.8. The development of appropriate methods for studying flour granulation has enabled investigators to study the relationship between flour granulation and cake quality. For example, Miller et al. (1967) showed that pin milling of soft wheat flour improves cakes quality. As the particle size of flour is decreased, cake volume increased. This improving effect is probably due to an increase in the number of free starch granules in the flour after pin-milling. Yamazaki and Donelson (1972) showed a definite negative correlation between particle size of soft wheat flour after pin milling and its cake volume potential.

Another important factor playing a role in production of desirable cakes are emulsifiers and emulsifier combinations. They improve cake quality by influencing grain quality and volume of the cakes. Today, it is possible through the selection of the proper emulsifier combination to improve the efficiency of flour to produce desirable cakes.

The objective of this project was to determine the cake making properties of three soft wheat flours of varying extraction: a good quality, short patent flour and two poor quality flours, a straight grade and a middle patent flour. The effects of particle size reduction and emulsifiers as factors affecting the performance of these flours were also studied.

LITERATURE REVIEW

Soft Wheat Flours

Soft wheat flour is made up of particles of various sizes, ranging downward from 150 μ to practically zero. The size of these particles is influenced both by the inherent nature of the wheat and the milling process. Unlike hard wheats where the end-product is almost invariably bread or other yeast-leavened baked products, soft wheats often are not milled as straight grade flours. Instead, soft wheats undergo split milling whereby a given group of similar streams are segregated for one use, while at the same time other streams are combined for other uses (Nelson and Loring, 1963). During soft wheat milling, the starch-protein bond ruptures easily and the kernel crushes with minimal force, releasing a large number of free starch granules. This is one of the reasons why soft wheats are used in a wide selection of end-products such as: cakes, cookies, doughnuts, and crackers (Hoseney and Seib, 1978). A typical soft wheat milled commercially may include from 16 to 28 streams, depending upon the size of the mill and the parameter of flow. Soft wheat flours may range from 50% extra short patent cake flour, to intermediate and long patents, to straights. Variations in the strength of soft wheat flours range from a low of 7.0-7.5% protein for cookies, to 10% protein or more for use in cracker sponge and doughnut flours. Treatments of flours may extend from untreated, as in cookies and pastry flours, to heavily bleached and chlorinated cake flours in the range of pH 4.5-4.8 (Nelson and Loring, 1963). The development of high ratio cakes is due to the introduction of special cake flour that yields superior volume, tenderness, and softness of the product (Rees, 1971). Such flour is a short patent that is extracted from the early breaks and middlings to produce a flour with the lowest protein and ash contents and the smallest uniform average particle size, and an extraction within the range of 45-65% of the total flour (Pyler, 1979). Furthermore, this flour is usually reduced in average particle size by passage through a pin mill or by other means and then treated with chlorine gas (Yamazaki, 1978).

To give satisfactory performance in cake products, the flour must yield a soft gluten which does not develop a significant degree of toughness during cake mixing. On the other hand, the protein content in the flour must possess sufficient strength to assure the formation of a fine light structure in the cake (Pyler, 1979). If the protein is too strong it will resist expansion during the baking process and yield tough-eating and low volume cakes. If too weak in protein, the cake batter may balloon up in the oven only to contract just before the setting process, shrinking from the tin sides and sinking in the middle (Rees, 1971). Bakers believe that the very short patent flours from soft wheat yield cakes with superior tenderness and softness of texture as compared to cakes from poor grade flours, and therefore cake flours have protein contents of 7.0-9.0% and an ash of 0.34-0.38% (Pyler, 1979).

Because of thc low content of protein, cake flours have a relatively low absorption. However, absorption in the case of cake flour is not synonymous with the term as used in breadmaking. Bread flour absorption is largely governed by protein content and gluten strength, two factors of great importance in bread production but a relatively minor significance in cake baking. Absorption in cake flours implies their liquid-carrying capacity, which should be as high as possible to produce an optimum product. Many factors can affect the liquid-carrying capacity of a flour and its ability to retain moisture in the finished product. Such factors include protein, ash and pentosan contents, extraction rate, pH, granulation, inherent nature, milling process and ingredients used in cake formula (Pyler, 1979; Miller et al., 1967; Kissell, 1959; Wilson and Donelson, 1963).

Soft wheat cake flour that is used in the baking of high ratio layer cake requires the use of chlorinated flour. The treatment of flour with the appropriate quantity of chlorine gas significantly improves the cake volume, internal quality and prevents collapse of the cake structure (Yamazaki and Kissell, 1978). The efficiency of flour chlorination as reflected in cake volume and internal score is associated with the amount of free starch available for chlorination as a function of particle size reduction (Miller et al., 1967). The reaction between chlorine and flour is surface dependent, thus chlorination is more effective with flours of smaller average particle size than those with larger particles (Wilson et al., 1964). Size reduction by pin milling separates starch granules from the protein matrices (endosperm chunk) and the protein particles are reduced to a very small size. The starch surface is greatly increased so that it becomes more exposed to chlorine gas (Yamazaki and Donelson, 1972). The benefits of chlorination only are obtained at specific levels of treatment. Below the optimum level, the batter expands well, but shrinks excessively upon cooling resulting in a low volume because of insufficient hydration of the starch granules. Above the optimum chlorination level, the batter expansion is restricted, so even though shrinkage is less, the cake still has a lower volume. Optimum chlorination is a compromise between expansion and contraction rates of the batter (Yamazaki and Kissell, 1978).

In spite of the studies done on chlorinated flour, the exact mechanism of chlorination improvements remains unclear. Chlorination would seem to affect many components of wheat flour; chlorine modifies flour proteins, lipids, and causes the depolymerization of starch (Tsen and Kulp, 1971; Kulp and Tsen, 1972). It is believed that the most important effect of chlorine is on the starch content. The solubility and water binding properties of starch increase with chlorination. In untreated cake flour it is believed that lipid coating of the granule inhibits the take-up of water, but chlorine treatment prevents the lipids from complexing with the starch, and so allows a greater absorption of water at a given temperature (Rees, 1971).

Another important flour parameter that has been investigated by many workers is flour granulation and its effect on cake quality. Measurement of particle size distribution of a flour is difficult because of its shape irregularity and the density differences among its components (Donelson and Yamazaki, 1972; Farrand, 1972). Nonetheless, many workers have found a relationship between flour granulation and cake quality through progress in the measurement of flour particle size distribution by utilizing the Coulter Counter, sedimentation, sieving and other similar means. Miller et al. (1967) showed that pin milling of soft wheat flour improves cake quality. As the particle size of flour is decreased, cake volume increased. However, the improving effect continues only until starch damage becomes excessive and counteracts the advantage of decreasing particle size. This improving effect is probably due to an increase in the number of free starch granules in the flour after pin-milling. Yamazaki and Donelson (1972) and Chaudhary et al. (1981) found a high negative correlation for white layer cake volume versus MMD (Mass Mean

Diameter--particle size above which 50% of flour weight lies) of laboratory milled cake flours obtained from pure wheats. Cake volume also was associated highly and inversely with MMD of straight grade hard wheats. A varietal difference was recognized among the wheats which were associated largely with inherent differences in endosperm friability. Furthermore, Chaudhary (1975) claimed that baking of the high protein fine fraction of air-classified flours showed that high protein and ash contents in flour are not determinants for producing layer cakes of satisfactory volumes if the flours are fine. This worker also emphasized the importance of starch exposure to chlorination as a primary factor in determining cake flour potential.

Another recent useful approach to flour granulation research is air size classification. Flour particles have been classified according to three broad fractions: 1) very fine (0-15 μ), high protein fraction; 2) intermediate sized (15-40 μ), low protein fraction largely composed of starch granules; 3) coarse fraction (>40 μ) composed of fragments of endosperm cells. This air size classification is useful because it allows the production, from one type of wheat, two or more types of flour with different protein contents meeting the protein requirements of different bakery products. Air classification also permits a miller or researcher to produce a uniform flour, minimizing the effect of variations in wheat due to climate, soil and variety (Gordon et al., 1964).

Emulsifiers

Emulsifiers are used widely in the baking industry in order to produce stable mixtures of fat-soluble and water soluble materials. Today, through progress in emulsifier technology, bakers are capable of producing cakes with: larger volume, higher degree of symmetry, more tenderness, better texture, softer crumb, better mouthfeel and longer shelf life. Most emulsifiers are esters or modified esters formed by the combination of polyalcohols with edible fatty acids or fats (Nash and Brickman, 1972). They are amphiphilic substances which possess both hydrophilic and lipophilic properties. They orient and lower the interfacial tension between fat and water phases and thus help emulsification of fat in the cake batter. At present, a wide variety of emulsifiers is used in baker's cakes, depending on the formula, type of production equipment, labelling attitudes and FDA regulations (Rusch, 1981). The selection of one emulsifier system for a particular use has become complex because of the many-food grade emulsifiers at present. To facilitate selection, emulsifiers were classified by four principles: 1) by the charge they carry in a solution; 2) by their degree of solubility in various solvents; 3) by the type of functional groups forming the hydrophilic part of the emulsifier; 4) by the HLB (Hydrophilic-Lipophilic Balance). HLB, simply, is a scale of 0-20 based on the molecular weight of the hydrophilic portion of the emulsifier molecule related to the total molecular weight of the molecule (Del Vecchio, 1975). The most prominent emulsifying agents used in the cake industry are: 1) mono- and diglycerides; 2) glycerol-lacto esters; 3) propylene glycol monoesters; 4) sorbitan fatty acid esters; 5) polysorbate fatty acid esters; 6) ethoxylated monoglycerides; 7) polyglycerol esters; and 8) stearoyl-2-lactylate (O'Brien, 1972).

Emulsifiers for the baking industry first were introduced in the early 1930's. These were mono- and diglycerides of fatty acids and primarily were used in the production of layer cakes (Hanamoto and Bean, 1977). The function of mono- and digycerides is to improve shortening efficiency by dispersing the fat into a finer globule size, thereby enhancing the ability of fat to incorporate air. This emulsifier system also interacts with the two main components of flour, namely starch and protein. Another function of this emulsifier is its ability to increase the strength of cake to carry a high proportion of sugar. In a high-ratio cake make with a nonemulsified shortening there is a tendency for the baked cake to suffer structure collapse or fall, apparently due to escessive starch gelatinization and rupture of granules due to structural weakness. The level of mono- and diglycerides in the shortening is very critical. Since the fineness of cake is a function of the concentration of this emulsifier, an increase in the level of the emulsifier brings about a decrease in the size of the creamed individual air bubbles and corresponding increase in their number. Beyond a critical concentration of this emulsifier in the shortening, a deterioration of quality sets in (Birnbaum, 1978).

Emulsifier combinations may be more effective than any single emulsifier for improving cake quality. Buddemeyer et al. (1962) and MacDonald (1968) showed that in cake systems, a multiple component emulsifier blend in a fluid shortening was more effective in improving air incorporation, lowering specific gravity, increasing cake volume and upgrading cake quality than a single component emulsifier. Knightly (1969) explained the advantage of using a combination of lipophilic and hydrophilic emulsifiers; if the emulsifier is not adequately dispersed, its efficiency per unit weight is reduced. A combination of lipophilic and hydrophilic emulsifiers will usually provide optimum performance, the latter aiding the dispersion of the former, in addition to providing improved emulsion stability on their own.

MATERIALS AND METHODS

Materials

The materials and their source are as follows:

(1) Three untreated cake flours of varying extraction milled from soft wheat: (I) Short patent (moisture 13.00%, ash 0.347%; protein 9.40%); (II) Middle patent (moisture 13.20%, ash 0.423%, protein 9.75%); (III) Straight grade (moisture 13.25%, ash 0.470%, protein 10.10%). Ash and protein for I, II and III were corrected to 14% moisture. The samples were obtained from the Pillsbury Co., Minneapolis, MN.

(2) Unemulsified shortening--Primex, Proctor and Gamble Co., Cincinnati, OH.

(3) Mono- and diglycerides (ATMUL #86K), Kraft Inc., Memphis, TN.

(4) Vanade, water dispersion of 32% Sorbitan Monostearate and 8% Polysorbate 60 with sodium propionate and sodium benzoate added as preservatives--Patco Products Co., Kansas City, MO.

(5) Double acting baking powder--Red Star, Universal Foods Co., Milwaukee, WI.

(6) Granulated sugar.

Procedure

Particle size reduction. Alpine Kolloplex Laboratory Mill 160Z was used to reduce the particle size of the three flours I, II, III. Each was passed through the mill at the same feed rate (454 g/min) and speed (14,000 RPM) as follows: none (0); once (1) and twice (2) to obtain three flours.

Chlorination. All flours were treated with chlorine gas to a flour pH of about 4.70 (the optimum level) at the Soft Wheat Quality Laboratory, USDA, Wooster, Ohio.

Particle size measurement. Flour particle size distribution for all flours was measured by MSA Sedimentation Particle Size Analysis (Whitby), (AACC method 50-10). Data are expressed by MMD (Mass Median Diameter--particle size in SED* above which 50% of flour weight lies, Table I).

Baking Formula

The cakes were baked using the simplified white layer lean cake formula developed by Kissell, 1959, in which eggs and milk were omitted to provide a sensitive test for the flour. This formula puts more responsibility for the structure producing ability of the flour and accents differences between flours under various treatments. Two slight modifications were made; the sugar was added separately instead of in a solution form; and the ingredients were scaled down so only a single 15.2 cc layer cake was baked (Spies, 1981). The following "lean formula cake method" is shown in the table below:

Ingredients	Quantity (g)	Flour Basis %
Flour	100	100
Sugar	130	130
Total emulsified shortening	27.9	27.9
Baking powder	4.7	4.7
Distilled water	Variable	Variable

*SED. Stokes Equivalent Diameter means: the volume equivalent of the particle volume, assuming a spherical shape. This is based on Stokes law, which relates to sedimentation in a non-interaction viscous medium, where it is assumed that streamlined motion for the particle reaches a constant terminal velocity.

TABLE I

Mass Median Diameter for All Samples Before and After Pin Milling*

Number	Flour	Pin-Milling Treatment	Mass Median Diameter (μ)
1	Short patent	0	25
2	Short patent	1	19
3	Short patent	2	17
4	Middle patent	0	29
5	Middle patent	1	19
6	Middle patent	2	17
7	Straight grade	0	26
8	Straight grade	1	19
9	Straight grade	2	17

*Refer to size distribution curves Fig. 1, 2 and 3.

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Fig. 1. Size distribution curve for short patent flour before and after pin milling.

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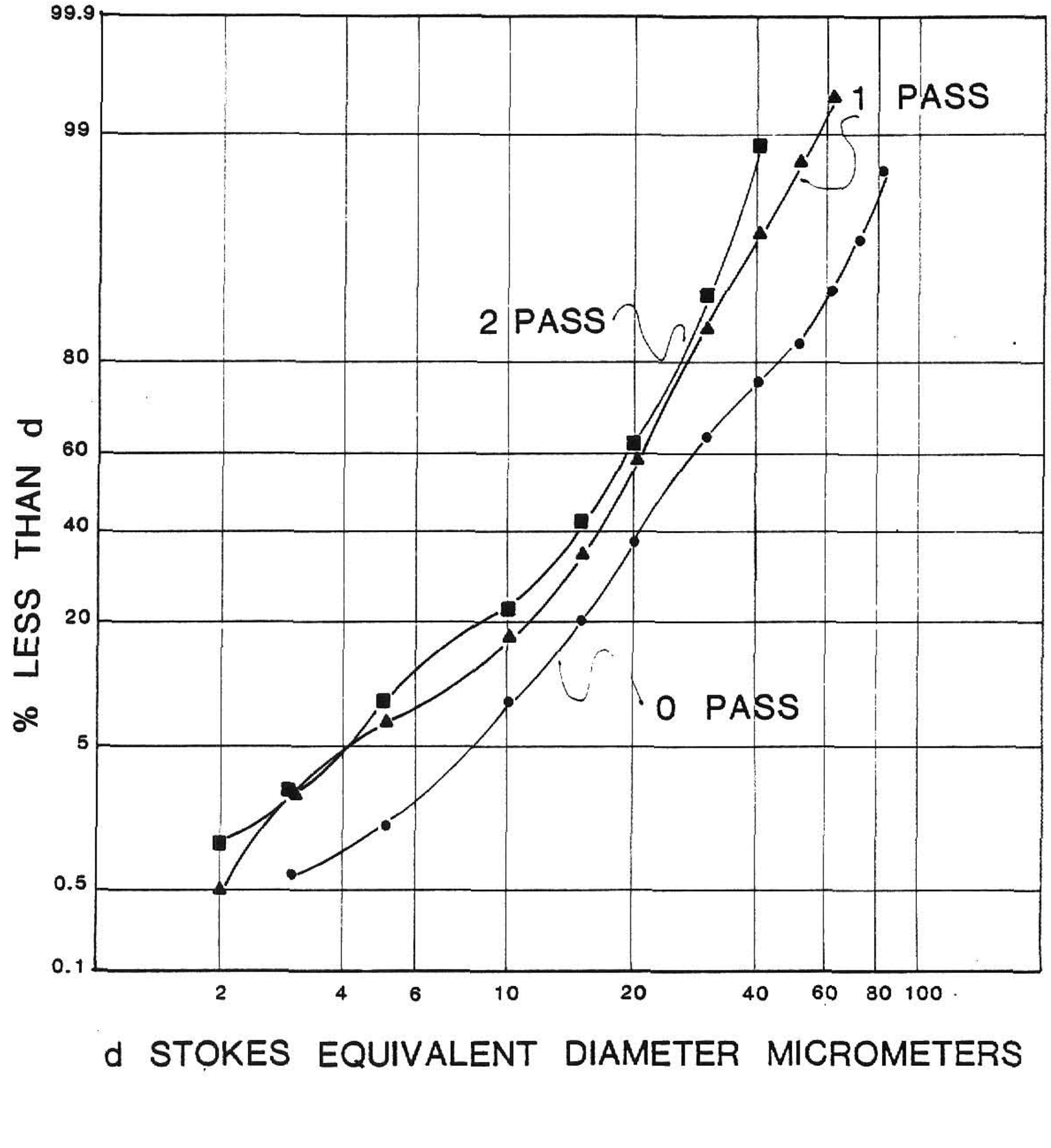
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Fig. 2. Size distribution curve for middle patent flour before and after pin milling.

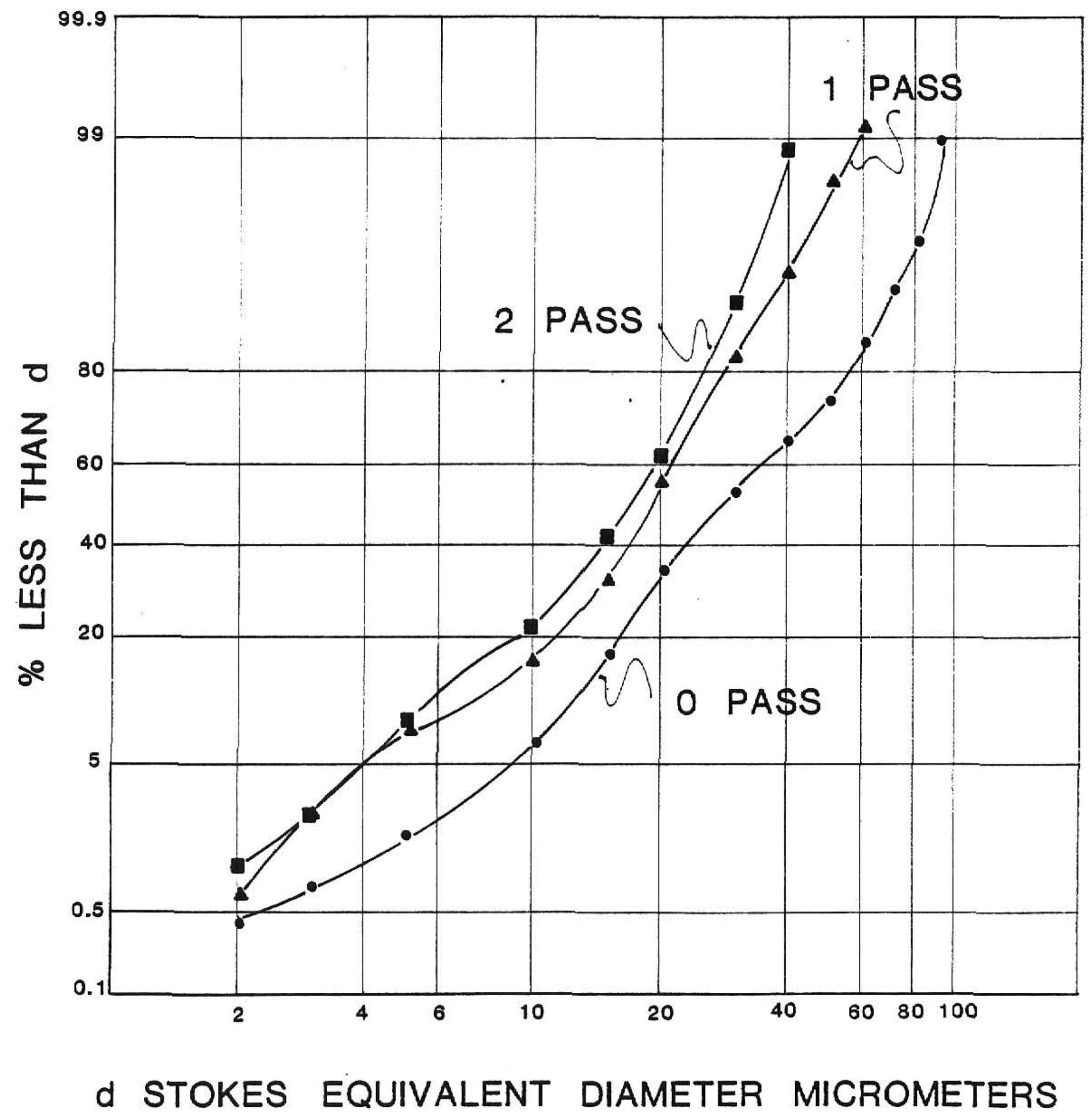
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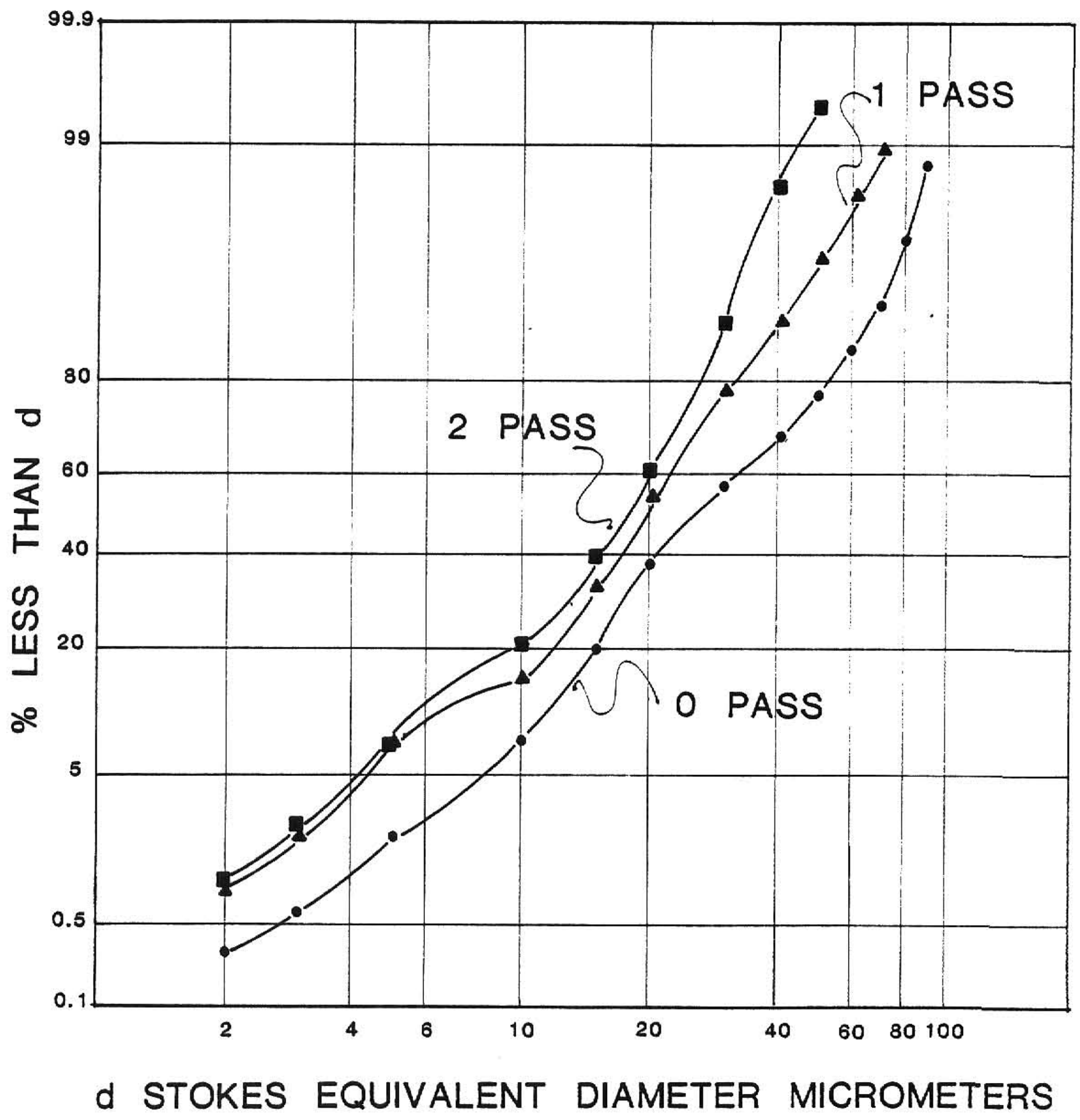
Fig. 3. Size distribution curve for straight grade flour before and after pin milling.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Baking Method

The requisite quantities of emulsifiers (% on total shortening weight basis) were blended with non-emulsified shortening by direct mixing at slow speed for 15 sec in a 3-quart bowl of the Hobart mixer (model C-100 equipped with an adapter) using a cake paddle. The bowl contents were scraped and mixed at slow speed further for 15 sec. The flour and baking powder were sifted and added to the bowl. Sugar and 59.3% of the requisite water were added. The contents were mixed for 0.5 min at low speed and then scraped down. Mixing was continued for 2.5 min at medium speed followed by a scraping down. A third mixing was given for 0.5 min at the same speed. The calculated remaining volume of water (depending upon the optimum water level for each flour) was added to the batter and was given a final mixing for 1.5 min at medium speed. The batter's specific gravity was measured and cakes (240 g batter in steel baking pans, greased on the inside and lined with 15.2 cm parchment circles) were baked at 190^{o}C for 21 min in a Reed reel oven. After 20 min of cooling, the cakes were removed from the pans and allowed to cool for an additional 20 min.

Determination of optimum water level for each flour. A series of cakes (ten water levels) were baked to ascertain the optimum water level for each flour. A round top countour, maximum cake volume and high cake grain quality score (fineness, uniformity of crumb cell distribution, and moistness by touch) were the criteria considered in determining the optimum water level for each specific flour. Baking formula and method were the same as above except for the use of a commercial emulsified shortening: Richtex, obtained from Kraft Industrial, Memphis, TN.

Quality Assessment

All quality assessments except specific gravity of batter were determined approximately 4½ hr after baking.

(1) Specific gravity of batter. The specific gravity of batter was determined at the end of mixing by dividing the weight of a given volume of batter by the weight of an equal volume of water.

(2) Cake volume and weight. Cake volume in cc was determined by rapeseed displacement. Weight was determined in g.

(3) Top contour. Top contour was determined by using AACC Method 10-91. Top contour index in cm = 2C-B-D. C is the vertical line between the center of top contour and cake base. B and D are vertical lines located 1.6 cm from the circumference of the cake.

(4) Cake grain quality. Cake grain quality was a composite unit for three characteristics: fineness, uniformity of crumb cell distribution and moistness by touch, each on scales of 1-10, with 10 being the highest quality. Evaluation was done by the principal investigator.

(5) Crumb firmness. Crumb firmness of cake was measured by a Voland-Stevens LFRA Texture Analyzer (Firmness Probe: TA5; penetration speed: 2.0 mm/sec; penetration distance: 4 mm). A section 2.2 cm thick was cut from the center of the cake. The piece was placed on the plaform below the probe so that the surface of the crumb to be tested was facing upwards. Three positions were chosen to test the crumb: crumb center portion, right and left portion. The average of the three readings was recorded as crumb firmness in g.

(6) Crumb color. The Agtron Multichromatic Abridged Reflectance Spectrophotometer (Model M-300) using the monochromatic spectral line of the blue mode (436 nm) was used for measuring crumb color. The scale was standardized using standard discs: 33 and 68 to read 0.0 and 100.0

respectively. Measurements on cake were carried out on a central crumb portion obtained by cutting horizontally through the center of one half. A black paper mask with two rectangular holes of 16.4 cm was used to block the escaping light at the edges of the sample and to standardize the reflectance area prior to undertaking the measurements.

Response Surface Design

Response Surface Methodology (RSM) was used to determine the optimum blend of the two emulsifiers at specified MMD of flour for each of the three flours. A Central Composite Rotatable Design in two independent variables at five levels was chosen as recommended by Cochran and Cox, 1957, Table 2. The practical range for the two variables was based on preliminary tests. The actual amount of the variables have been coded so that the smallest amounts appear as: (-1.414) and the largest amounts appear as: (+1.414) (Table 3). Each flour required 12 combinations of the emulsifiers. Since there were nine flours, the complete design required 108 cakes which were baked in a randomized sequence. Six dependent responses were measured for each combination. These were: specific gravity, volume, top contour, grain quality, crumb firmness, and crumb color.

TABLE II

Central Composite Rotatable Design for Two Variables, with Five Levels

Test Number	Independent Variables X_2	X_3
1	-1	-1
2	+1	-1
3	-1	+1
4	+1	+1
5	-1.414	0
6	+1.414	0
7	0	-1.414
8	0	+1.414
9	0	0
10	0	0
11	0	0
12	0	0

TABLE III

Actual Value of Coded Levels of Independent Variables

Independent Variable (Emulsifiers)	Coded Levels (% on Total Shortening Wt) Basis				
	-1.414	-1	0	+1	+1.414
MONODI	0	1.4	5	8.6	10
VANADE	0	1.8	6.1	10.4	12.2

RESULTS AND DISCUSSION

The response surface of this experiment is modeled by:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_{11}X_1^2 + \beta_{22}X_2^2 + \beta_{33}X_3^2 + \beta_{12}X_1X_2$$
$$+ \beta_{13}X_1X_3 + \beta_{23}X_2X_3 + \text{Error}$$

where:

Y : The dependent response such as cake volume or grain quality . . .

β_0: Intercept

X_1: Mass Median Diameter

X_2: Monodi

X_3: Vanade

The coefficients β_1, β_2, β_3, β_{11}, . . . are estimated from the data. $\beta_1X_1 + \beta_2X_2 + \beta_3X_3$ is called linear or 1st order effect. $\beta_{11}X_1^2 + \beta_{22}X_2^2 + \beta_{33}X_3^2$ is called quadratic or 2nd order effects. $\beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{23}X_2X_3$ is called cross product effects.

Effect of Emulsifiers at Specified MMD of Flour on Quality of Cake Made with Short Patent Flour

Tables 4 to 6 contain actual and coded level of Monodi (mono- and diglycerides) and Vanade at specified Mass Median Diameter of short patent flour for all treatment combinations, along with the resultant data obtained for cake volume, top contour, grain quality, crumb firmness, crumb color and batter specific gravity. Table 7 contains the estimates and R^2 values for the six response equations. The measure of fit (R^2) explains the degree to which the observed results fit the generated equation.

TABLE IV

Design of Experimental Pattern to Determine Effects of MONOD1 and Vanade on Batter and Cake Quality of Cakes Made with Short Patent Flour, MMD = 25 μ

Number	Actual* and Coded Level of MONOD1	Actual* and Coded Level of Vanade	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	1.4 (-1)	1.8 (-1)	600	0.8	18	75	70	1.03
2	8.6 (+1)	1.8 (-1)	640	1.9	18	70	71	1.06
3	1.4 (-1)	10.4 (+1)	625	1.7	20	57	70	0.98
4	8.6 (+1)	10.4 (+1)	635	0.8	5	69	70	0.92
5	0.0 (-1.414)	6.1 (0)	575	1.7	19	65	71	0.99
6	10.0 (+1.414)	6.1 (0)	600	-0.1	12	66	70	0.98
7	5.0 (0)	0.0 (-1.414)	590	1.2	18	70	71	1.07
8	5.0 (0)	12.2 (+1.414)	620	2.8	18	65	70	0.94
9	5.0 (0)	6.1 (0)	640	1.9	20	60	70	0.98
10	5.0 (0)	6.1 (0)	625	2.1	22	62	71	0.97
11	5.0 (0)	6.1 (0)	625	2.3	20	61	71	1.00
12	5.0 (0)	6.1 (0)	640	2.1	21	60	70	0.98

*% on total shortening wt. basis.

TABLE V

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Short Patent Flour, MMD, 19 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	625	1.6	20	74	71	1.04
2	660	2.6	22	69	71	1.08
3	650	3.0	20	55	70	0.97
4	660	1.9	9	70	70	0.92
5	670	1.8	24	66	72	1.02
6	630	1.8	20	64	71	1.02
7	625	2.6	22	70	71	1.01
8	640	0.7	22	64	72	0.90
9	650	2.4	20	61	70	0.97
10	670	2.5	26	62	72	0.99
11	660	2.3	28	61	71	1.01
12	650	2.4	27	62	70	0.99

*Refer to Table IV for key to number sequence.

TABLE VI

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Short Patent Flour, MMD = 17 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	635	1.8	22	75	71	1.04
2	675	2.6	23	69	72	1.07
3	690	3.6	20	56	70	0.99
4	690	1.5	10	70	70	0.90
5	690	1.2	24	67	72	1.02
6	660	1.6	22	66	71	0.98
7	650	2.5	24	70	72	1.07
8	660	2.1	22	61	71	0.94
9	695	3.0	27	60	72	0.99
10	690	3.1	28	59	70	1.01
11	680	3.2	27	60	71	1.04
12	680	2.9	29	61	70	1.01

*Refer to Table IV for key to number sequence

TABLE VII

The Effect of Emulsifiers and MMD of Flour on Batter and Quality of Cake Made with Short Patent Flour--Estimates and R^2 Values for the Response Equations

	Estimates for the Response Surface Equation					
Parameter[a]	Volume	Top Contour	Grain Quality	Crumb Firmness	Crumb Color	Specific Gravity
Intercept	1177.345	5.712	8.676	79.462	71.048	1.393
Linear						
X_1	-48.317	-0.421	0.847	0.671	0.117	-0.032
X_2	0.785	0.763	4.496	-3.976	-0.048	0.00016
X_3	12.0064	0.107	2.082	-4.746	-0.144	-0.0037
Quadratic						
X_1^2	0.937	0.0071	-0.033	-0.017	-0.0052	0.00069
X_2^2	-0.541	-0.040	-0.264	0.221	0.0060	0.00037
X_3^2	-0.551	0.0097	-0.153	0.175	0.0044	-0.00011
Cross Product						
X_1X_2	0.423	-0.0083	-0.058	0.0076	0.0013	0.00019
X_1X_3	-0.042	0.0099	0.021	0.013	0.0035	0.000096
X_2X_3	-0.511	0.038	-0.210	0.307	-0.011	-0.0016
R^2	0.7966	0.6654	0.8414	0.9026	0.2710	0.8741

[a] X_1 = MMD; X_2 = Monodi; X_3 = Vanade.

R_2 value of 1 would indicate that all observed data values fit the model equation exactly. R^2 which falls below 0.6 would indicate either that the model equation is unable to satisfy the observed response or there is an experimental error. In the table, R^2 of volume, grain quality, crumb firmness and specific gravity was high (ranging from R^2 = 0.796 to 0.902). The R^2 of top contour was fair (0.665) but, only 0.271 of the variation in crumb color was explained by the prediction equation, showing that the studied independent variables (Mass Median Diameter of flour, Monodi and Vanade) had little effect on this response in this experiment.

After estimating the response surface models, we evaluated each of them at many different values of the independent variables (e.g., Mass Median Diameter = 16 μ-30 μ, 2 μ; Monodi = 0%-10%, 2%; and Vanade = 0%-14.0%, 2%). Examination of the results indicated that the combination of independent variables that gave the best results on all dependent variables was: Mass Median Diameter = 17 μ (Pin milling--twice reduced); Monodi = 5.0%; and Vanade = 6.1%. The predicted values resulting from this combination of factors are: cake volume = 685cc, cake top contour = 2.9 cm, cake grain quality = 27 units; cake crumb firmness = 60.5 g; cake crumb color = 71; and cake batter specific gravity = 1.00.

The surface response of this experiment showed that a combination of Monodi and Vanade was more effective in improving cake quality than each one alone. This is similar to results reported by Buddemeyer et al. (1962) who showed that in a cake system, a multiple-component emulsifier blend was more effective in increasing cake quality than a single component emulsifier. Figures 4 and 9 are three-dimensional response surfaces obtained by a statistical analysis system (SAS) program. Cake volume and grain quality are displayed with both Monodi and Vanade as variables and

Fig. 4. Three-dimensional response surface of cake volume (cc) for short patent flour (Mass Median Diameter = 25 μ, none reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR SHORT PATENT FLOUR

MASS MEDIAN DIAMETER=25

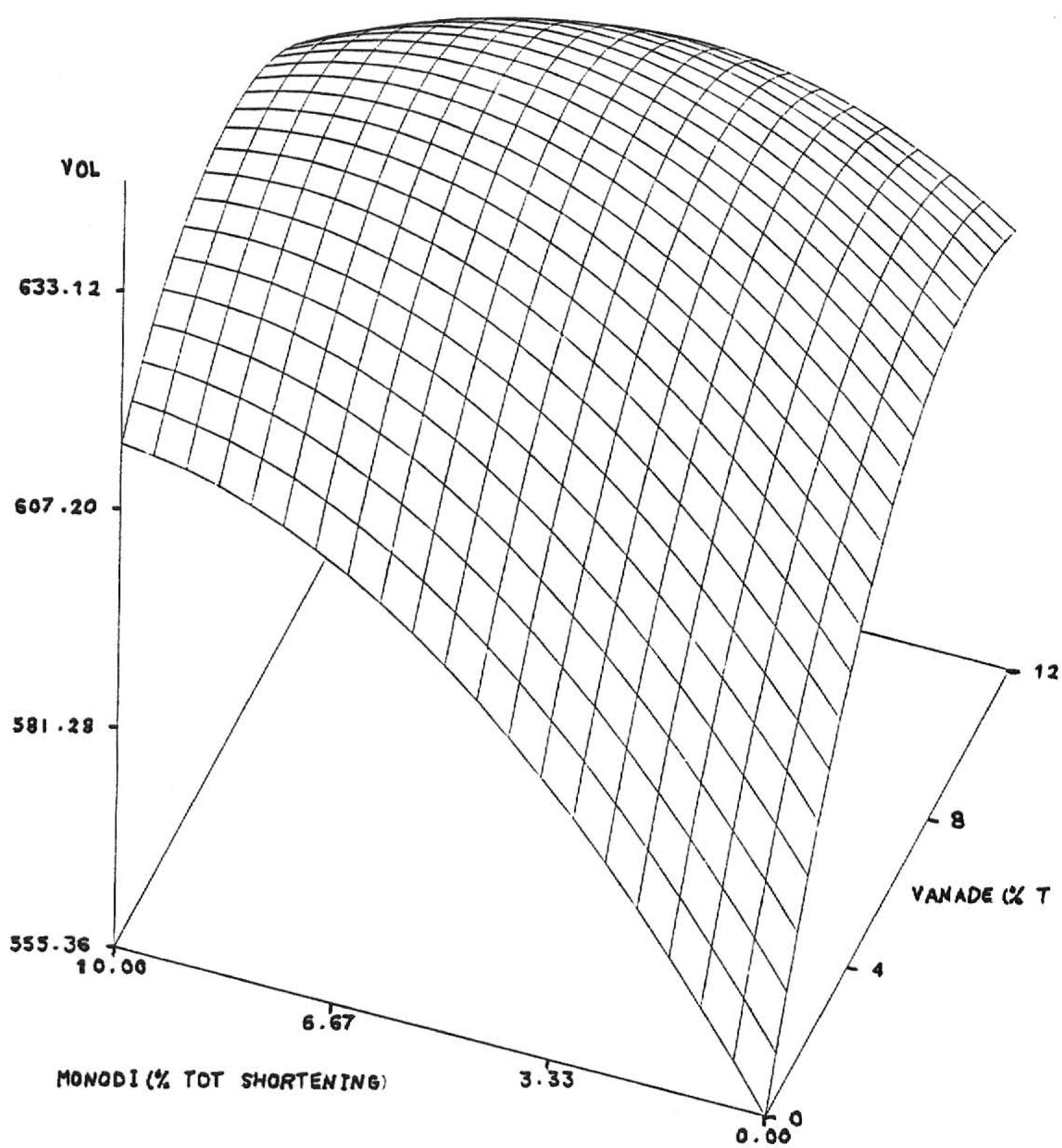


Fig. 5. Three-dimensional response surface of cake volume (cc) for short patent flour (Mass Median Diameter = 19 μ, once reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR SHORT PATENT FLOUR

MASS MEDIAN DIAMETER=19

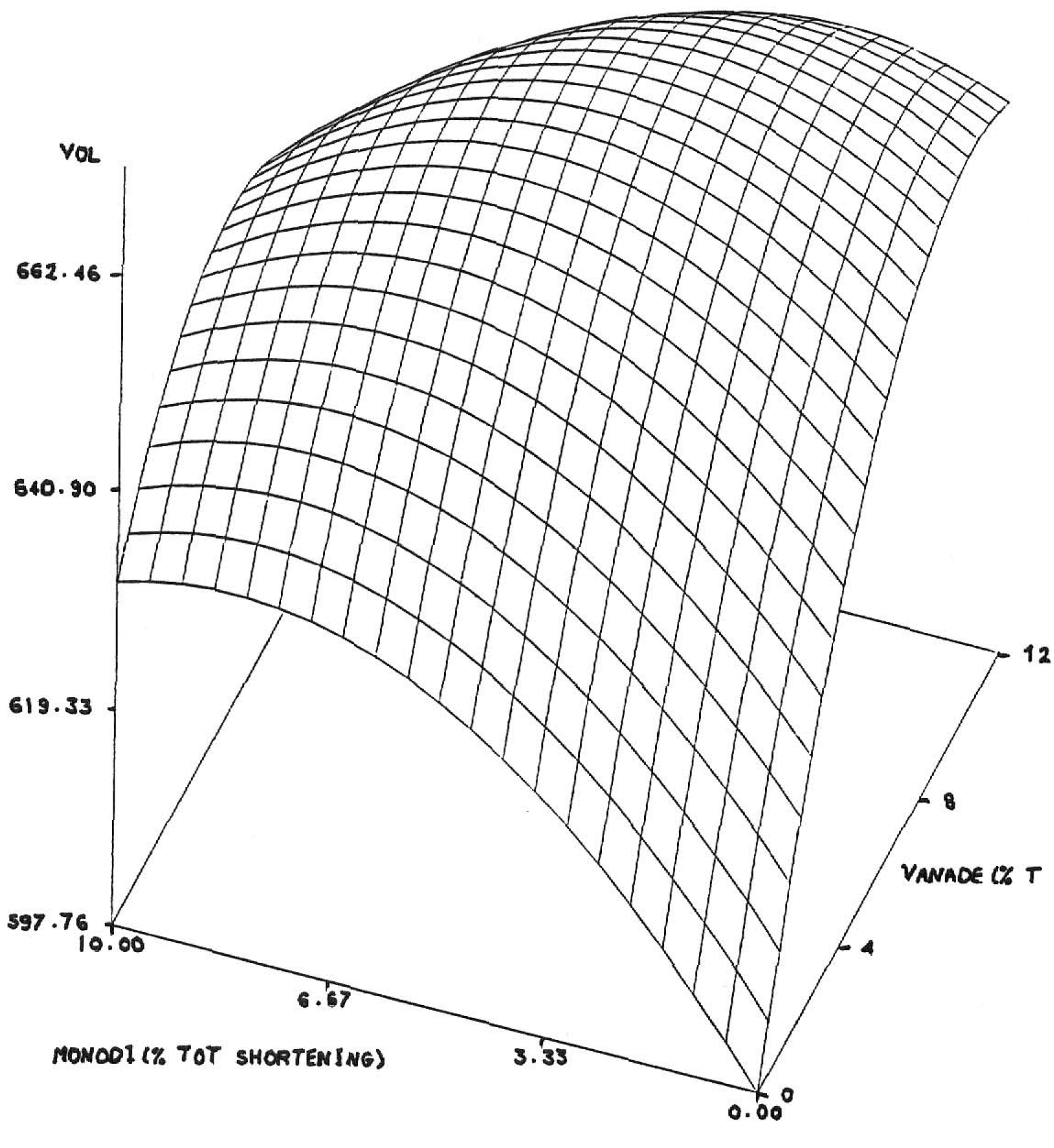


Fig. 6. Three-dimensional response surface of cake volume (cc) for short patent flour (Mass Median Diameter = 17 μ, twice reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR SHORT PATENT FLOUR

MASS MEDIAN DIAMETER=17

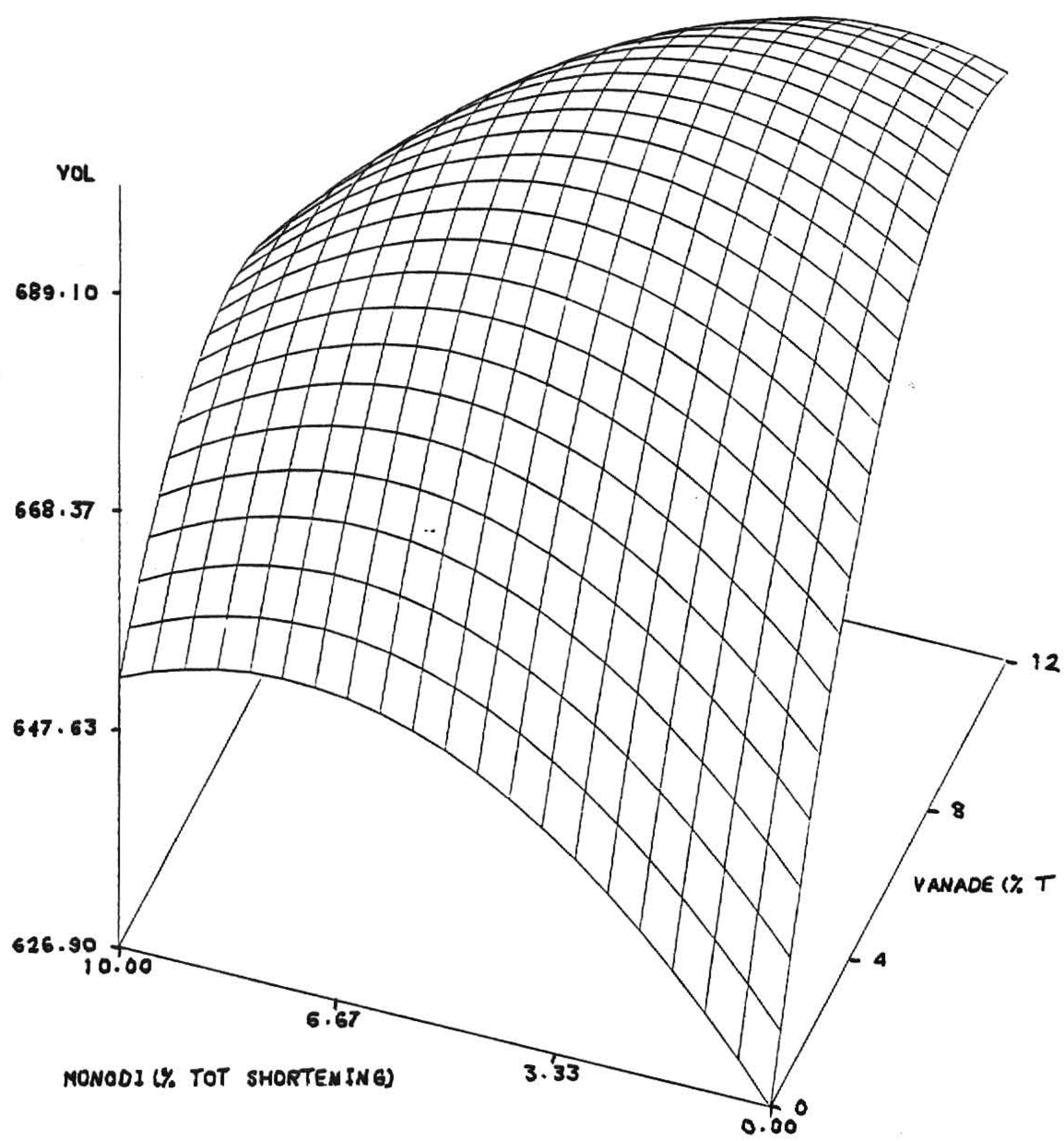


Fig. 7. Three-dimensional response surface of cake grain quality (units) for short patent flour (Mass Median Diameter = 25 μ, none reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR SHORT PATENT FLOUR

MASS MEDIAN DIAMETER=25

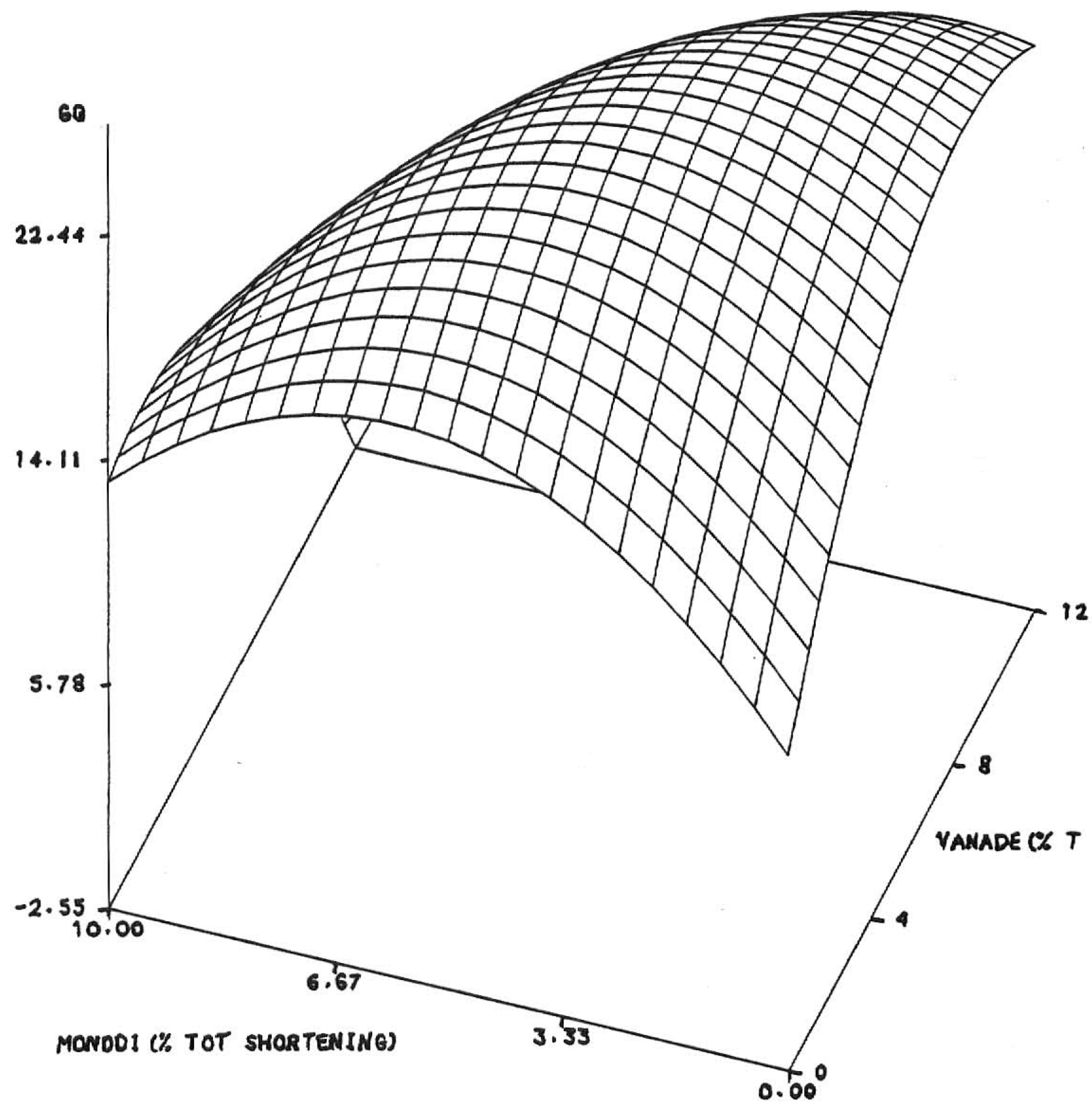


Fig. 8. Three-dimensional response surface of cake grain quality (units) for short patent flour (Mass Median Diameter = 19 μ, once reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR SHORT PATENT FLOUR

MASS MEDIAN DIAMETER=19

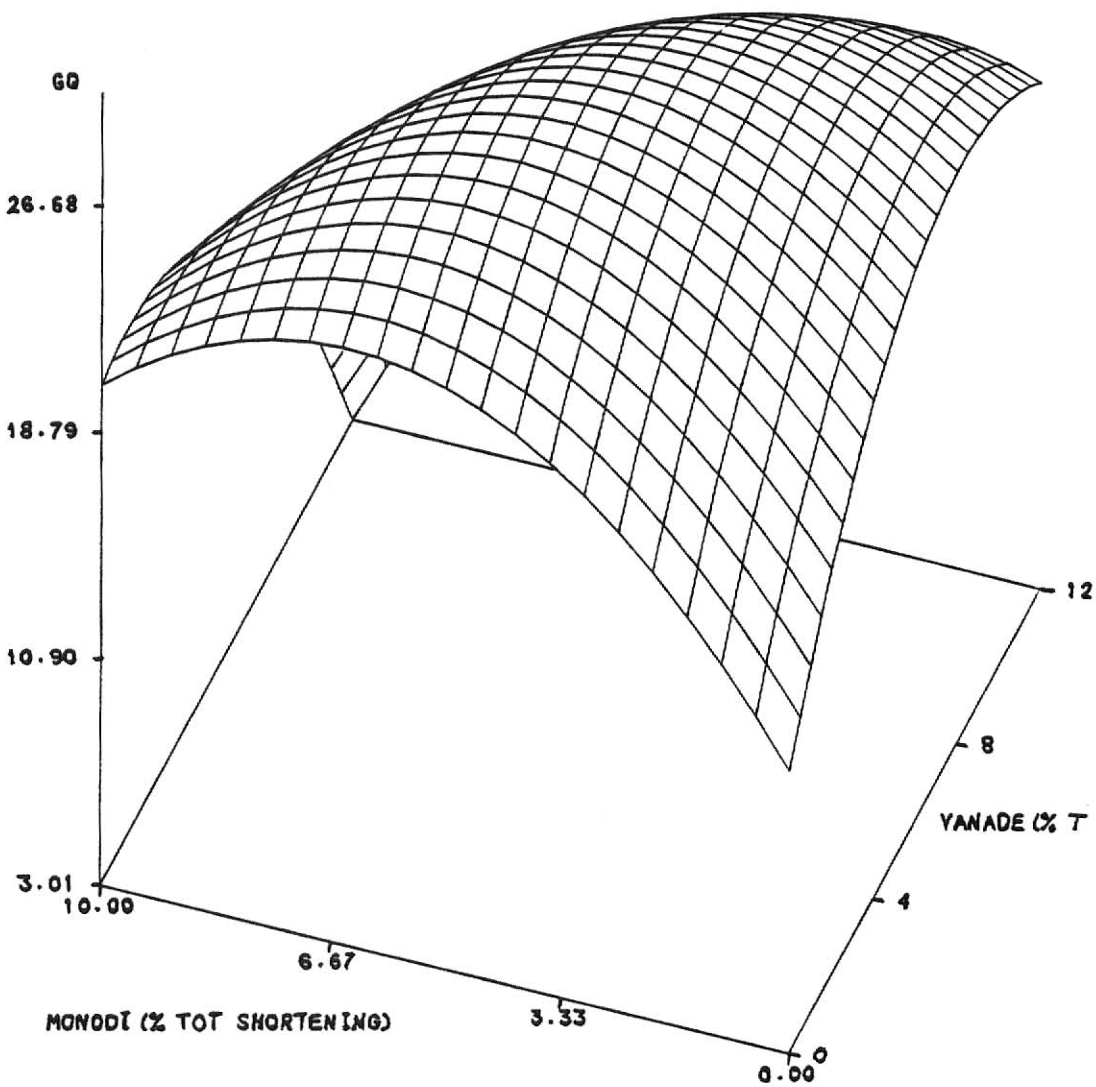
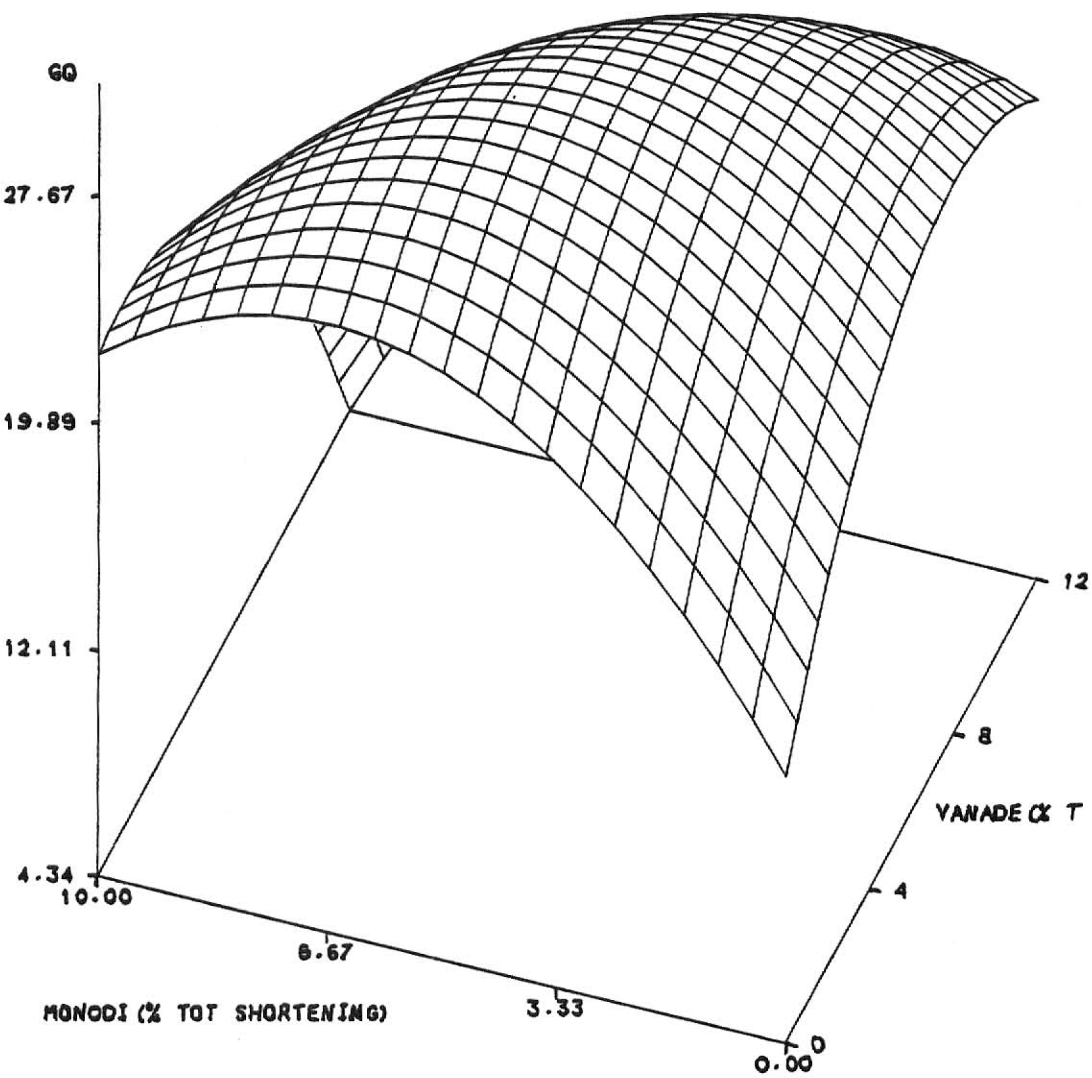


Fig. 9. Three-dimensional response surface of cake grain quality (units) for short patent flour (Mass Median Diameter = 17 μ, twice reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR SHORT PATENT FLOUR

MASS MEDIAN DIAMETER=17



Mass Median Diameter of flour is held constant at 25 μ, 19 μ and 17 μ (none, once and twice pin milling reduced, respectively). These figures indicate that the short patent flour that was reduced twice through the Alpine Mill (MMD = 17 μ) produced cake of larger volume (689.10 cc) and better grain quality (27.61 unit) than the same flour which was reduced none and once (MMD = 25 μ and 19 μ respectively) under the same combination treatments of Monodi and Vanade. This is similar to results reported by Miller and Yamazaki who showed that pin milling of soft wheat flour improved cake quality. As the particle size of flour is decreased cake volume increased. This improving effect is probably due to an increase in the number of free starch granules in the flour after pin milling (Miller et al., 1967; Yamazaki and Donelson, 1972).

Effect of Emulsifiers at Specified MMD of Flour on Quality of Cake Made with Middle Patent Flour

The actual and coded levels of Monodi and Vanade at specified Mass Median Diameter of middle patent flour for all treatment combinations, along with resultant data obtained for cake colume, top contour, grain quality, crumb firmness, crumb color and cake batter specific gravity are shown in Tables 8 to 10. Table 11 contains the estimates and R^2 values for the six response prediction equations. The measure of fit (R^2) of volume, grain quality, crumb firmness and specific gravity to the response surface was very high, as shown by R^2 (ranging from 85% to 95%). The R^2 of cake top contour was fair (61%), but only 22% of the variation in crumb color was explained by the prediction equation, showing again that particle size and emulsifiers had little effect on this response in this experiment.

After estimating the response surface models, we evaluated each of them at many different levels of the independent variables (e.g., Mass

TABLE VIII

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Middle Patent Flour, MMD = 29 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	525	0.3	4	78	53	1.03
2	600	-0.3	5	97	52	1.05
3	625	-1.5	4	56	53	0.97
4	610	-1.7	1	84	53	0.93
5	550	-0.1	6	70	54	0.99
6	540	-1.1	1	99	52	0.99
7	550	0.3	4	98	53	1.09
8	600	-0.1	1	71	54	0.90
9	600	-0.1	6	67	54	1.01
10	575	-0.2	7	68	53	0.98
11	600	-0.3	6	69	52	0.98
12	590	-0.1	5	68	53	0.99

*Refer to Table IV for key to number sequence.

TABLE IX

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Middle Patent Flour, MMD = 19 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	550	-0.3	8	91	54	1.03
2	625	1.5	8	81	53	1.08
3	650	1.6	8	70	53	0.99
4	620	0.2	1	64	53	0.91
5	575	0.7	7	70	54	1.01
6	600	-0.1	1	80	54	0.98
7	580	1.2	6	81	52	1.08
8	625	0.5	2	70	54	0.93
9	640	-0.5	8	68	52	0.98
10	625	-0.2	7	69	54	0.98
11	625	-0.2	9	67	53	0.97
12	630	-0.5	8	69	54	0.99

*Refer to Table IV for key to number sequence.

TABLE X

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Middle Patent Flour, MMD = 17 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	600	0.2	8	90	53	1.04
2	650	0.1	8	82	54	1.06
3	675	2.9	8	72	54	0.99
4	640	0.2	1	63	53	0.93
5	600	-0.4	7	72	52	1.02
6	625	-0.2	1	82	52	0.98
7	600	0.4	6	83	53	1.06
8	640	1.6	2	72	54	0.93
9	660	1.8	8	67	53	0.98
10	650	1.6	8	69	54	1.00
11	650	1.6	7	67	52	0.98
12	650	1.8	9	68	52	0.97

*Refer to Table IV for key to number sequence.

TABLE XI

The Effect of Emulsifiers and MMD of Flour on Batter and Quality of Cakes Made with Middle Patent Flour--Estimates and R^2 Values for the Response Equations

	Estimates for the Response Surface Equation					
Parameter[a]	Volume	Top Contour	Grain Quality	Crumb Firmness	Crumb Color	Specific Gravity
Intercept	783.971	4.722	2.618	133.175	47.203	1.0612
Linear						
X_1	-22.245	-0.4899	0.3579	-2.746	0.5380	-0.00059
X_2	24.158	0.3526	0.7696	-9.0016	0.1602	-0.0027
X_3	13.894	0.4020	0.9107	-4.377	-0.0992	-0.0065
Quadratic						
X_1^2	0.3867	0.0108	-0.0147	0.0438	-0.0111	0.0000085
X_2^2	-1.209	-0.0225	-0.1044	0.3954	0.00021	0.00052
X_3^3	-0.3562	0.0076	-0.08006	0.2756	0.0089	0.00043
Cross Product						
X_1X_2	-0.0373	-0.00064	0.0187	0.2635	-0.0102	0.00019
X_1X_3	0.1148	-0.0162	0.0106	-0.0488	0.0021	-0.00016
X_2X_3	-1.507	-0.0291	-0.0969	0.0646	2.2888	-0.0014
R^2	0.8709	0.6108	0.8738	0.8582	0.2219	0.9504

[a] X_1 = Mass Median Diameter; X_2 = Monodi; X_3 = Vanade.

Median Diameter = 16 μ-30μ), 2 μ; Monodi = 0%-10%, 2%; and Vanade = 0%-14%, 2%). Examination of the results indicated that the combination of independent variables that gave the best results on all dependent variables was: Mass Median Diameter = 17 μ (twice reduced), Monodi = 5.0%; and Vanade = 6.1%. The predicted values resulting from this combination of factors are: volume = 651 cc, cake top contour = 1.1 cm; cake grain quality = 8.0 units; cake crumb firmness = 67 g; cake crumb color = 53; and batter specific gravity = 0.98.

The surface response of this flour showed that as particle size decreased cake volume increased. Figures 10 to 12 are three dimensional response surfaces obtained by SAS program. Cake volume is displayed with both Monodi and Vanade as variables and MMD of flour is held constant at 29 μ, 19 μ and 17 μ (none, once and twice pin milling reduced respectively). These figures indicate that middle patent flour that was reduced twice through the Alpine mill (MMD = 17μ) produced cake of larger volume 662.36 cc) than the same flour which was reduced none and once (MMD = 29 μ and 19 μ respectively) under the same combination treatments of Monodi and Vanade. Figures 13 to 15 show effects on grain quality as a function of particle size and emulsifier combinations. In these figures, it is noticed that decreasing particle size improved grain quality by few units. In comparison with short patent flour, middle patent flour produced cakes with lower volume, reduced grain quality, higher crumb firmness, darker crumb color and lower top contour. Middle patent flour is characterized by higher levels of ash, protein, and presumably other materials such as pentosans, that are richer in the lower grade flour streams utilized in this flour. These components are likely a factor in the poorer baking performance of the middle patent flour, by some unknown mechanism.

Fig. 10. Three-dimensional response surface of cake volume (cc) for middle patent flour (MMD = 29 μ, none reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR MIDDLE PATENT FLOUR

MASS MEDIAN DIAMETER=29

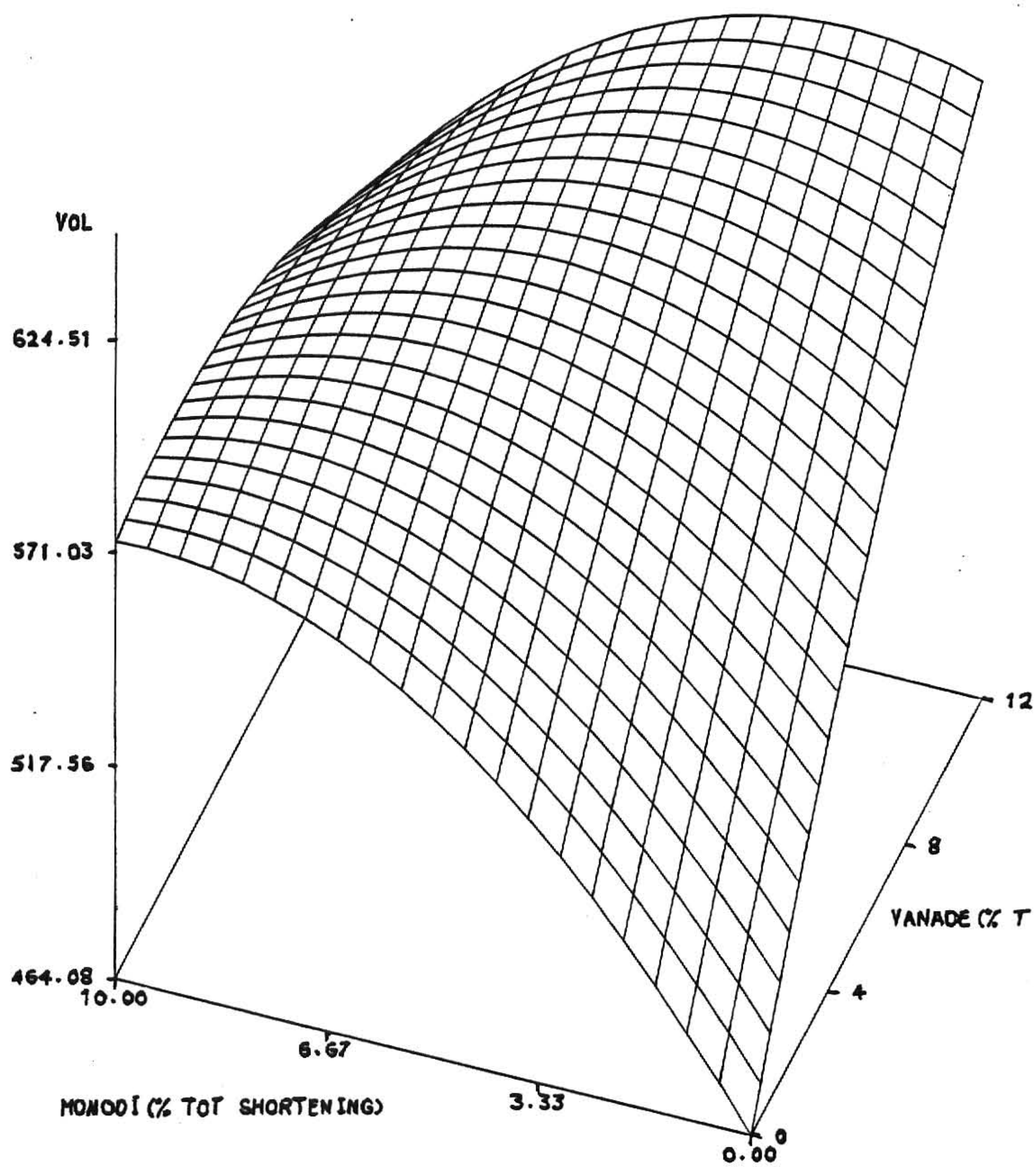


Fig. 11. Three-dimensional response surface of cake volume (cc) for middle patent flour (MMD = 19 μ, once reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR MIDDLE PATENT FLOUR

MASS MEDIAN DIAMETER=19

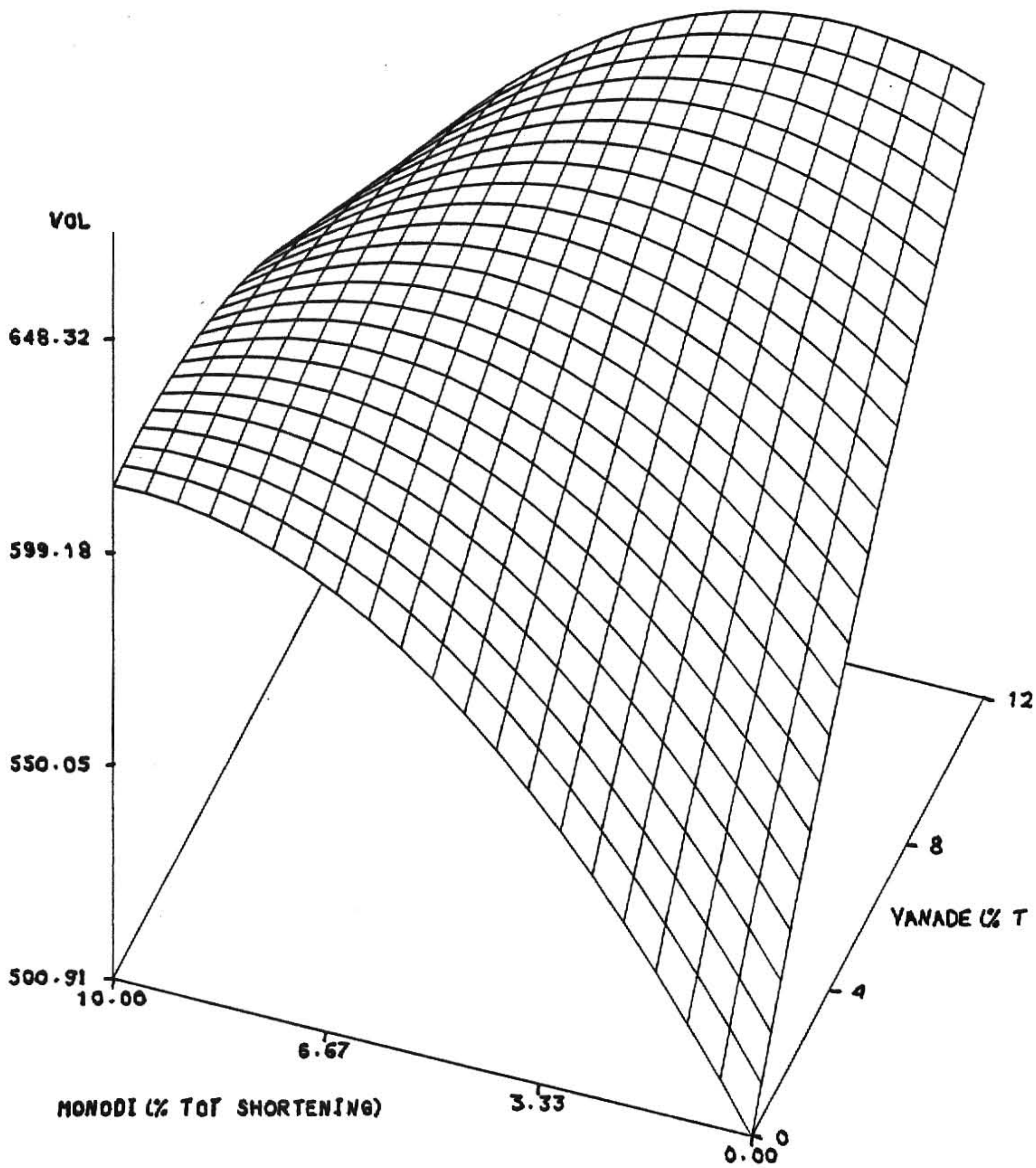


Fig. 12. Three-dimensional response surface of cake volume (cc) for middle patent flour (MMD = 17 μ, twice reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR MIDDLE PATENT FLOUR

MASS MEDIAN DIAMETER=17

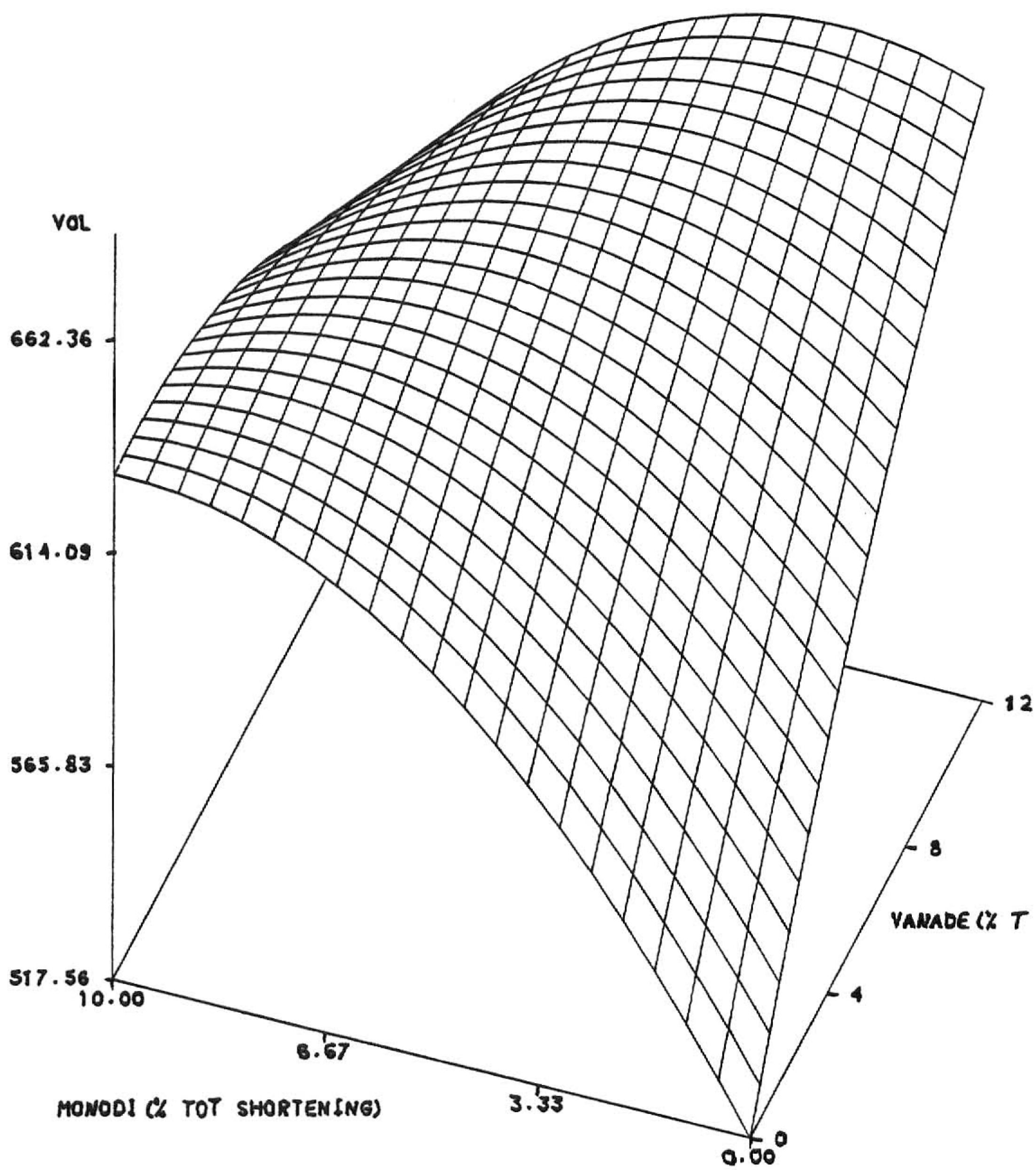


Fig. 13. Three-dimensional response surface of cake grain quality (units) for middle patent flour (MMD = 29 μ, none reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR MIDDLE PATENT FLOUR

MASS MEDIAN DIAMETER=29

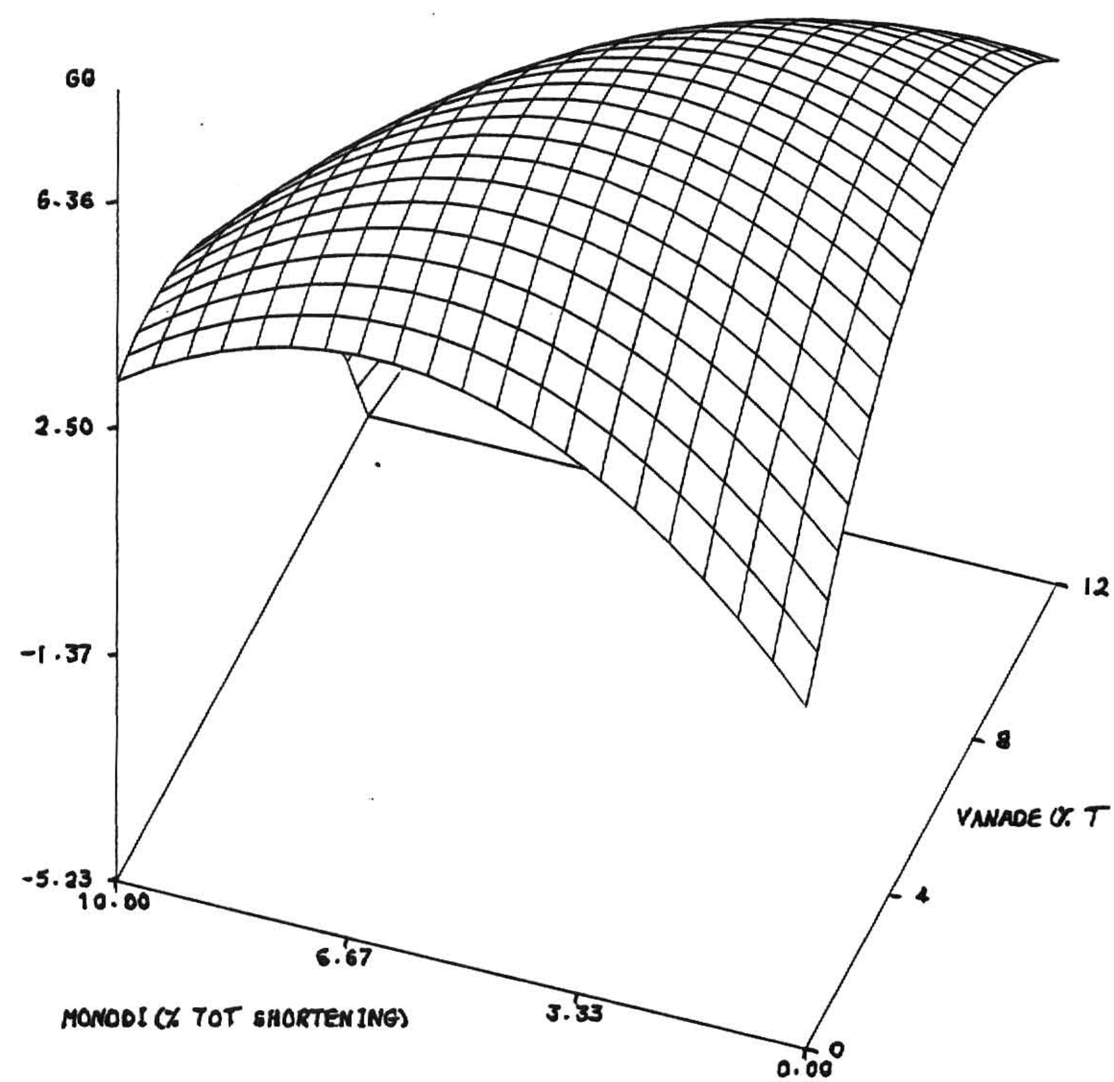


Fig. 14. Three-dimensional response surface of cake grain quality (units) for middle patent flour (MMD = 19 μ, once reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR MIDDLE PATENT FLOUR

MASS MEDIAN DIAMETER=19

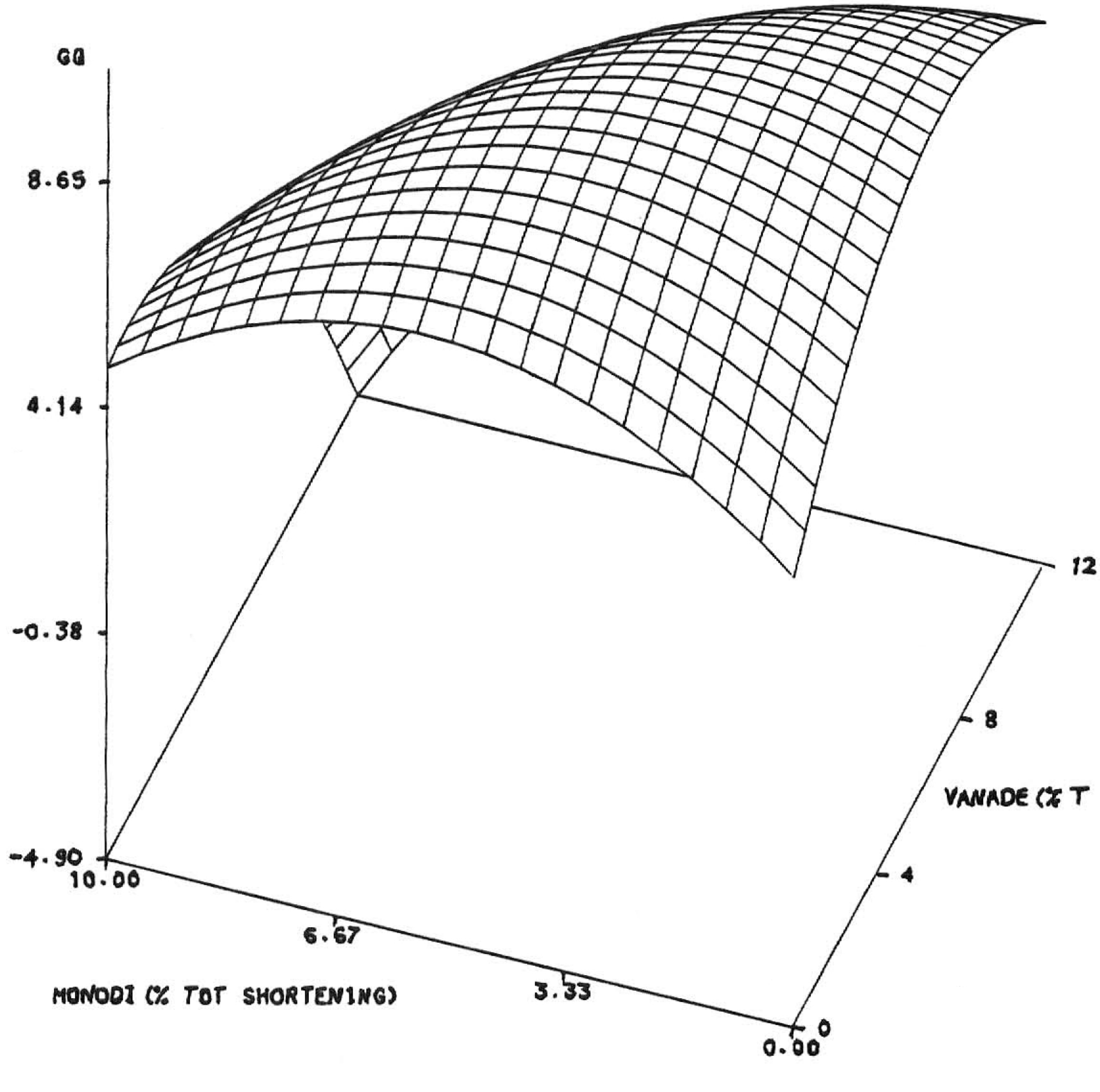
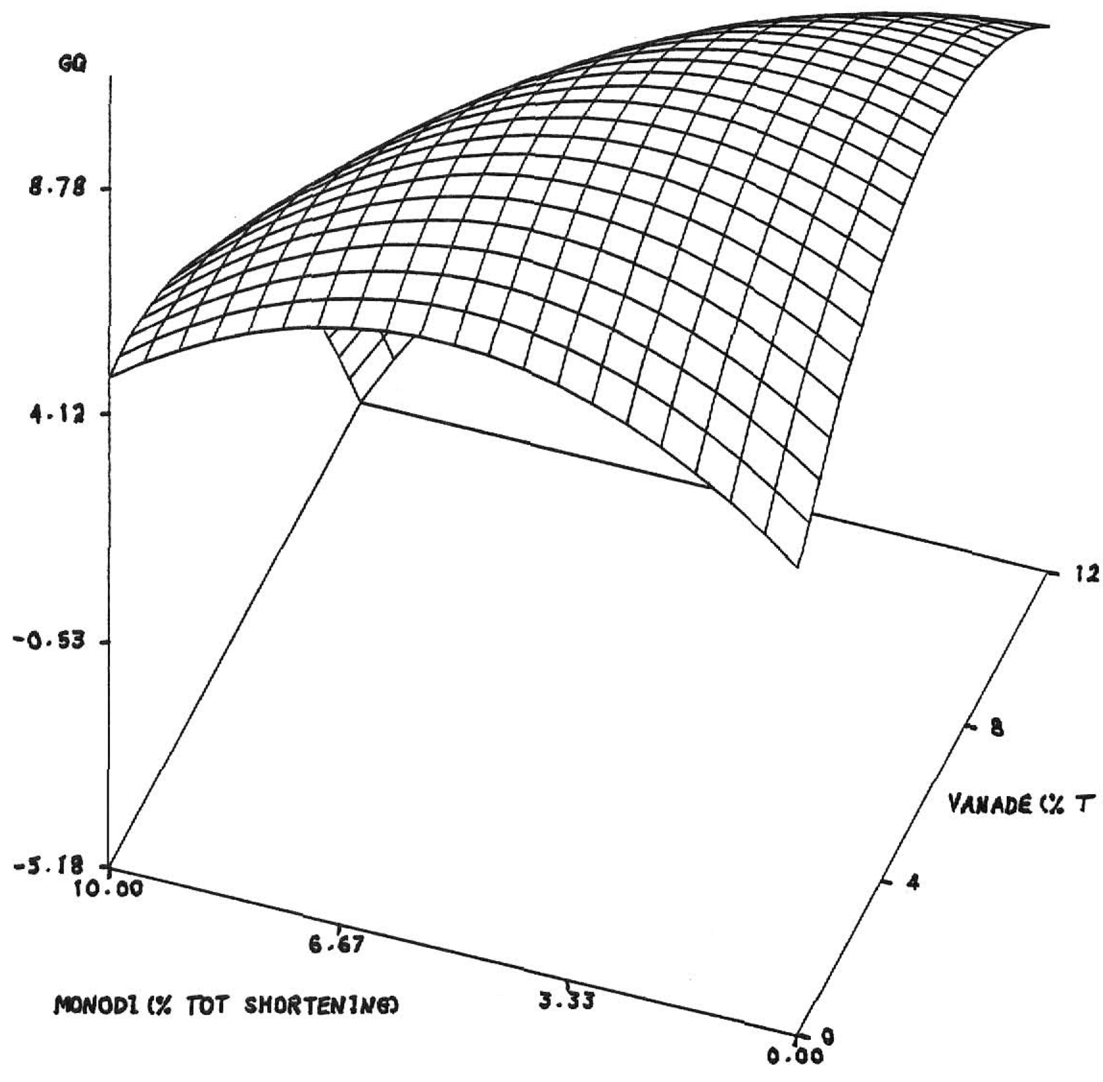


Fig. 15. Three-dimensional response surface of cake grain quality (units) for middle patent flour (MMD = 17 μ, twice reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR MIDDLE PATENT FLOUR

MASS MEDIAN DIAMETER=17



Effects of Emulsifiers at Specified MMD of Flour on Quality of Cake Made with Straight Grade Flour

The actual and coded levels of Monodi and Vanade at specified Mass Median Diameter of straight grade flour for all treatment combinations, along with resultant data obtained for cake volume, top contour, grain quality, crumb firmness, crum color and cake batter specific gravity are shown in Tables 12 to 14. Table 15 contains the estimates and R^2 values for the six response prediction equations. The measure of fit (R^2) of volume, grain quality, crumb firmness and specific gravity to the response surface was very high (ranging R^2 = 86% to 92%). The R^2 of cake top contour was fair (64%), but only 16% of the variation in crumb color was explained by the prediction equation, showing as before that particle size and emulsifiers had little effect on this response in this experiment.

After estimating the response surface models, we evaluated each of them at many different levels of the independent variables (e.g. mass median diameter = 16 μ-30 μ, 2 μ; Monodi = 0%-10%, 2% and Vanade 0%-14%, 2%). Examination of the results showed that the combination of independent variables that gave the best results on all dependent variables was: Mass Median Diameter = 17 μ (twice reduced); Monodi = 5.0%; and Vanade = 6.1%. The predicted values of this combination of factors are: volume = 674 cc; cake top contour = 1.5 cm; cake grain quality = 10.0 units, cake crumb firmness = 69 g, cake crumb color = 43; and cake batter specific gravity = 1.00.

The surface response of this flour showed that reducing particle size of flour improved cake volume. Figures 16 to 18 are three dimensional response surfaces obtained by SAS program. Cake volume is displayed with both Monodi and Vanade as variables and MMD of flour is held constant

TABLE XII

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Straight Grade Flour, MMD = 26 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	550	0.6	6	82	44	1.02
2	575	2.2	6	82	45	1.05
3	565	1.7	8	63	44	0.98
4	600	0.6	4	69	43	0.92
5	525	0.7	8	71	44	1.03
6	575	0.2	1	90	45	0.99
7	550	0.1	6	76	44	1.07
8	600	-0.4	4	59	44	0.93
9	620	1.7	8	65	43	1.00
10	630	1.8	7	66	45	0.98
11	625	2.2	8	64	44	1.00
12	610	1.8	7	65	45	0.98

*Refer to Table IV for key to number sequence.

TABLE XIII

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Straight Grade Flour, MMD = 19 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	560	1.8	7	91	45	1.03
2	625	1.3	6	91	44	1.05
3	580	2.4	10	63	43	0.99
4	625	-0.5	4	70	44	0.92
5	575	0.7	9	73	43	1.03
6	600	-1.1	1	99	45	1.02
7	610	1.2	9	74	44	1.08
8	650	2.1	8	60	44	0.94
9	630	2.0	8	70	44	0.99
10	650	1.9	8	72	45	0.99
11	640	1.7	9	70	43	0.98
12	650	1.8	9	71	44	1.01

*Refer to Table IV for key to number sequence.

TABLE XIV

Effect of Emulsifiers on Batter and Cake Quality of Cakes Made with Straight Grade Flour, MMD = 17 μ

Number*	Volume (cc)	Top Contour (cm)	Grain Quality Units (30)	Crumb Firmness (g)	Crumb Color	Specific Gravity
1	580	1.4	7	91	43	1.04
2	650	3.1	6	89	44	1.06
3	600	2.7	10	63	45	0.99
4	635	0.4	2	68	43	0.91
5	600	1.5	10	72	44	1.01
6	650	0.2	1	96	44	0.99
7	625	3.1	9	76	45	1.06
8	660	3.0	10	61	44	0.92
9	650	1.9	10	69	44	1.00
10	675	2.2	9	71	44	1.01
11	675	1.9	10	69	43	0.98
12	675	2.0	9	72	43	1.01

*Refer to Table IV for key to number sequence.

TABLE XV

The Effect of Emulsifiers and MMD of Flour on Batter and Quality of Cakes Made with Straight Grade Flour--Estimates and R^2 Values for the Response Equations

Parameter[a]	Estimates for the Response Surface Equation					
	Volume	Top Contour	Grain Quality	Crumb Firmness	Crumb Color	Specific Gravity
Intercept	996.487	18.530	11.839	58.435	40.075	0.9047
Linear						
X_1	-41.0028	-1.654	-0.4059	3.773	0.3189	0.0139
X_2	33.642	0.4111	0.6981	-4.945	-0.0169	0.0018
X_3	10.173	0.2686	0.8805	-3.236	0.0751	-0.0053
Quadratic						
X_1^2	0.807	0.0347	0.0033	-0.1012	-0.0066	-0.00034
X_2^2	-2.376	-0.0500	-0.1387	0.6135	0.0047	0.000503
X_3^2	-0.832	-0.00304	-0.0216	-0.0139	0.0033	0.0000303
Cross Product						
X_1X_2	-0.151	0.0139	0.0283	-0.0256	0.0051	-0.000022
X_1X_3	0.171	-0.00059	-0.0103	0.0475	-0.0037	0.000071
X_2X_3	-0.242	-0.0489	0.0201	0.1077	0.0161	-0.0015
R^2	0.9194	0.6456	0.8807	0.8626	0.1658	0.9442

[a]X_1 = Mass Median Diameter; X_2 = Monodi; X_3 = Vanade.

at 26 μ, 19 μ and 17 μ (none, once and twice pin milling reduced respectively). These figures indicate that straight grade flour that was reduced twice through the Alpine mill (MMD = 17 μ) produced cake of larger volume (674.13 cc) than the same flour which was not reduced or reduced once (MMD = 26 μ and 19 μ respectively) under the same combination treatments of Monodi and Vanade. In Figures 19 and 21 cake grain quality is displayed in a similar fashion as cake volume. In these figures, it is noticed that neither particle size nor emulsifiers increased grain quality, to the extent obtained with short patent flour. In comparison with short patent flour, straight grade flour, like middle patent flour, produced lower cake volume, reduced grain quality, higher crumb firmness, darker crumb color and lower top contour. The high quantity of ash, protein and presumably other materials are likely responsible in reducing the performance of this flour to produce good quality cake.

Fig. 16. Three-dimensional response surface of cake volume (cc) for straight grade flour (MMD = 26 μ, none reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR STRAIGHT GRADE FLOUR

MASS MEDIAN DIAMETER=26

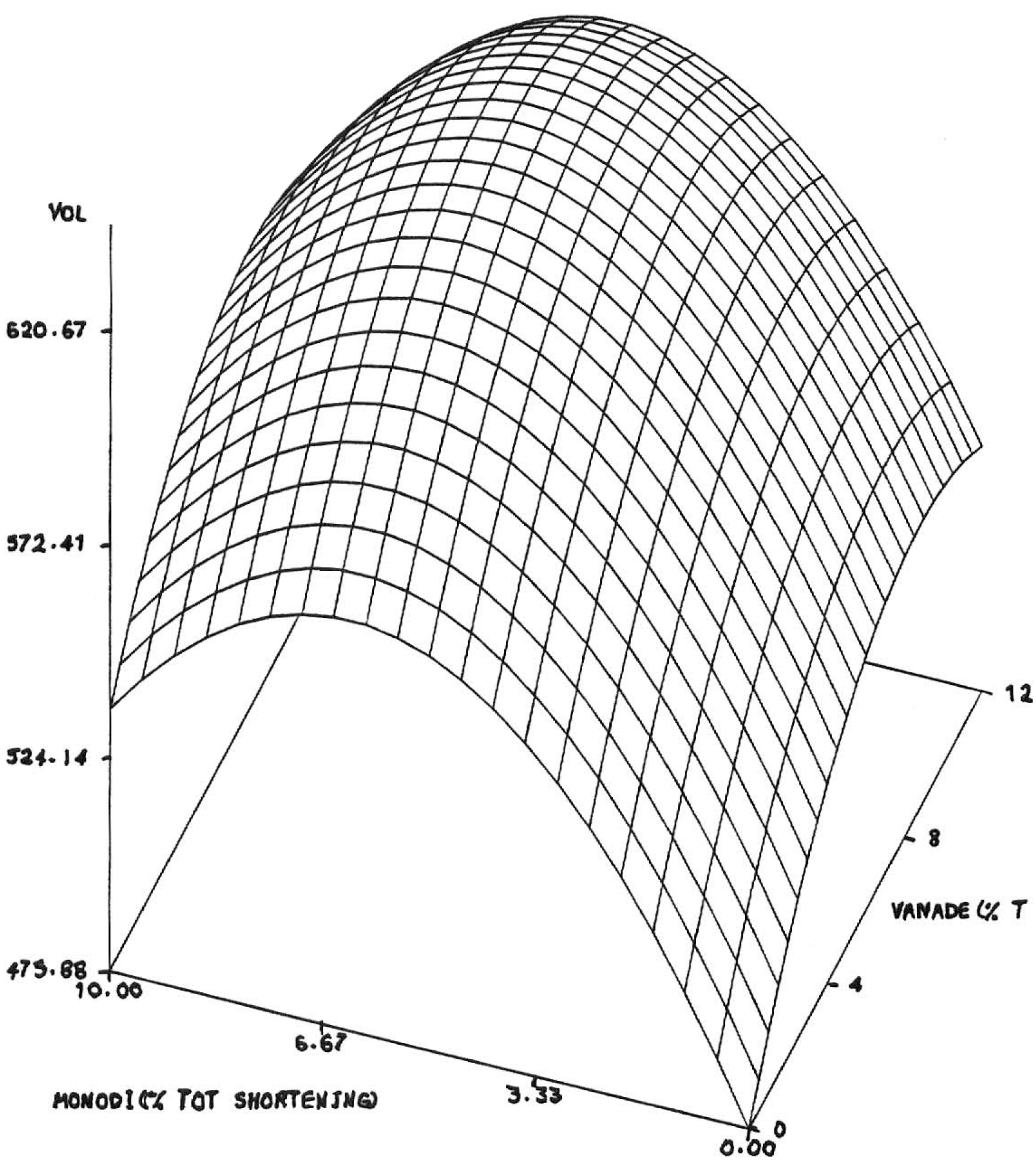


Fig. 17. Three-dimensional response surface of cake volume (cc) for straight grade flour (MMD = 19 μ, once reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR STRAIGHT GRADE FLOUR

MASS MEDIAN DIAMETER=19

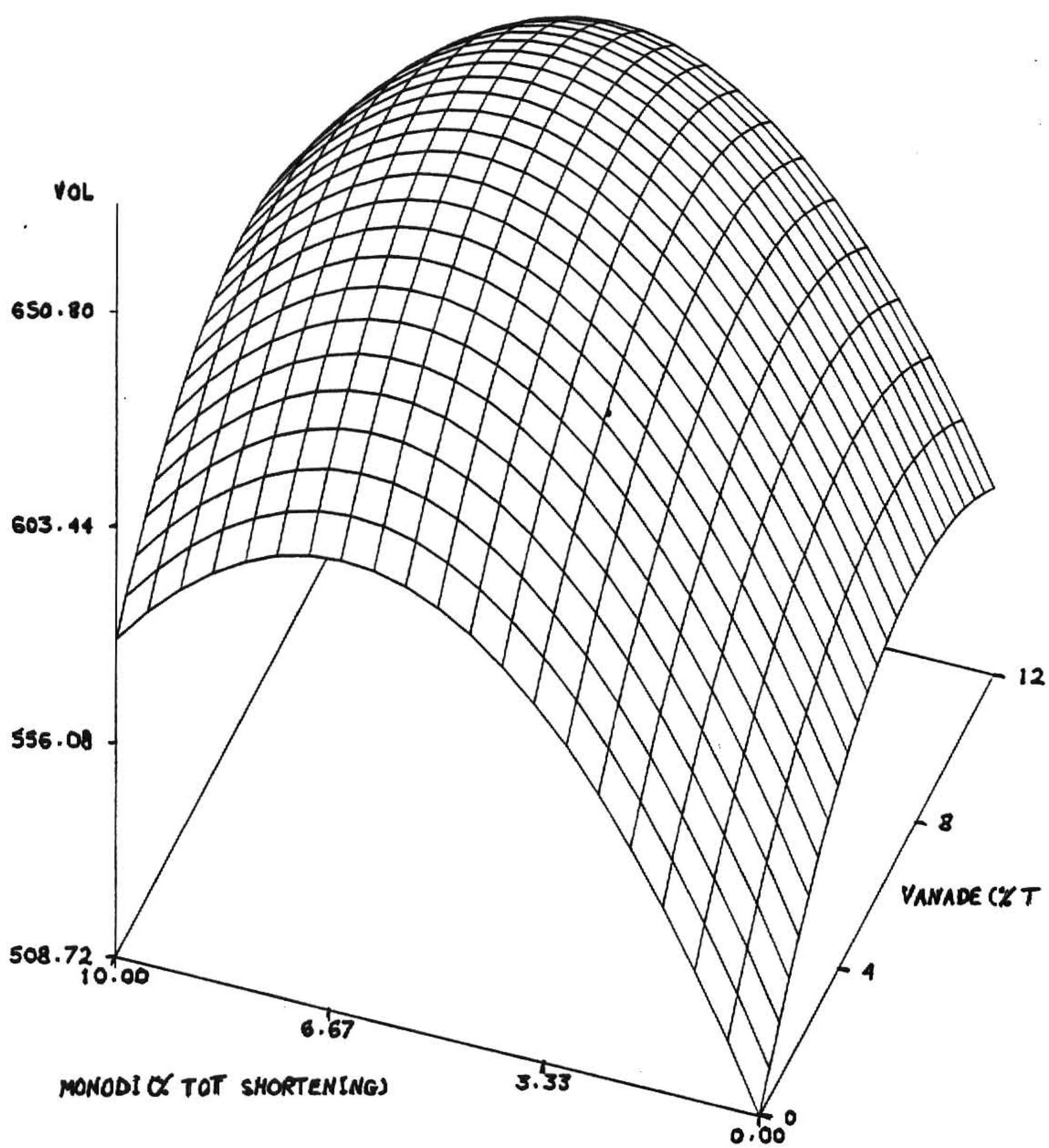


Fig. 18. Three-dimensional response surface of cake volume (cc) for straight grade flour (MMD = 17 μ, twice reduced) as a function of Monodi and Vanade.

CAKE VOLUME FOR STRAIGHT GRADE FLOUR

MASS MEDIAN DIAMETER=17

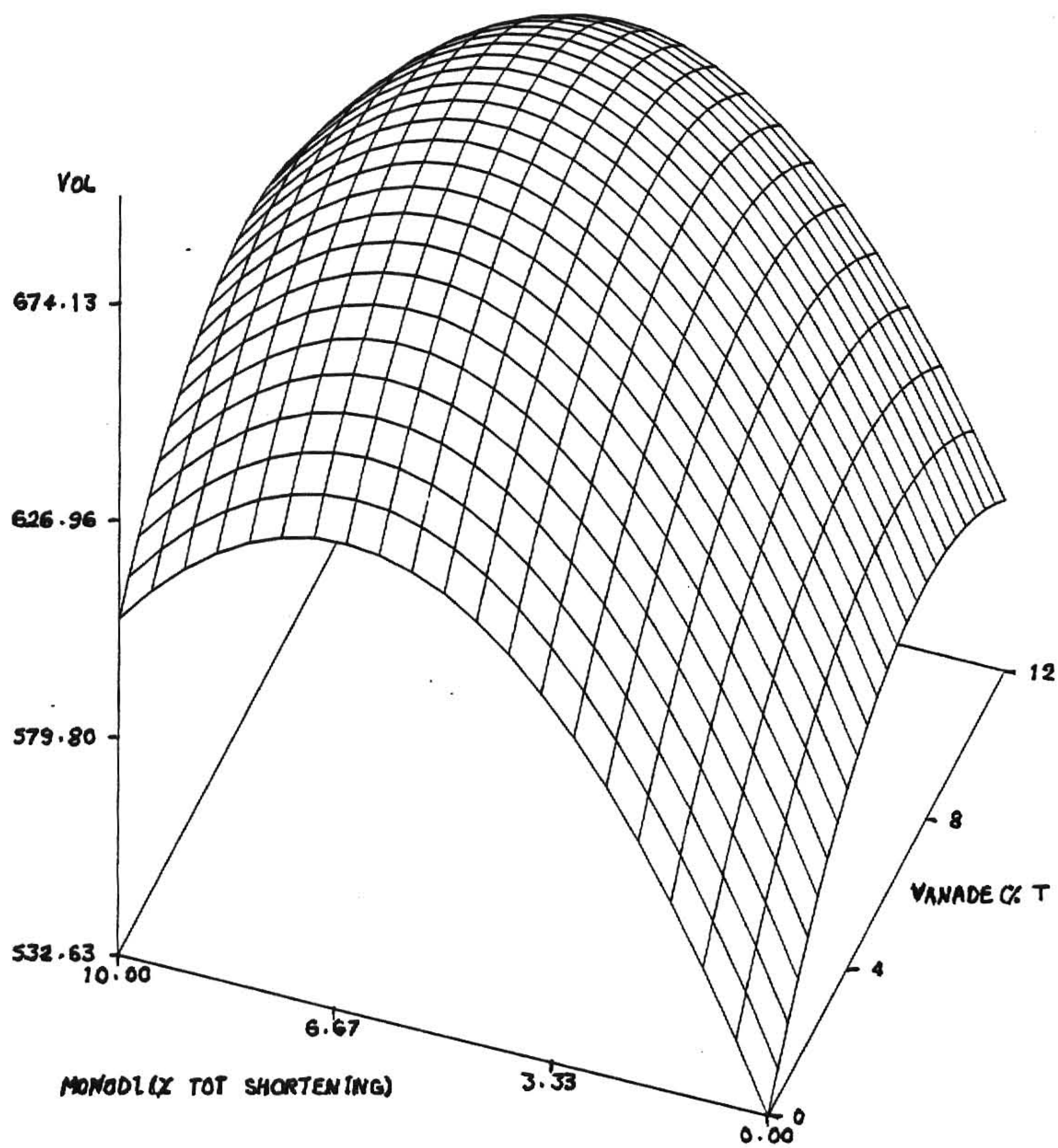


Fig. 19. Three-dimensional response surface of cake grain quality (units) for straight grade flour (MMD = 26 μ, none reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR STRAIGHT GRADE FLOUR

MASS MEDIAN DIAMETER=26

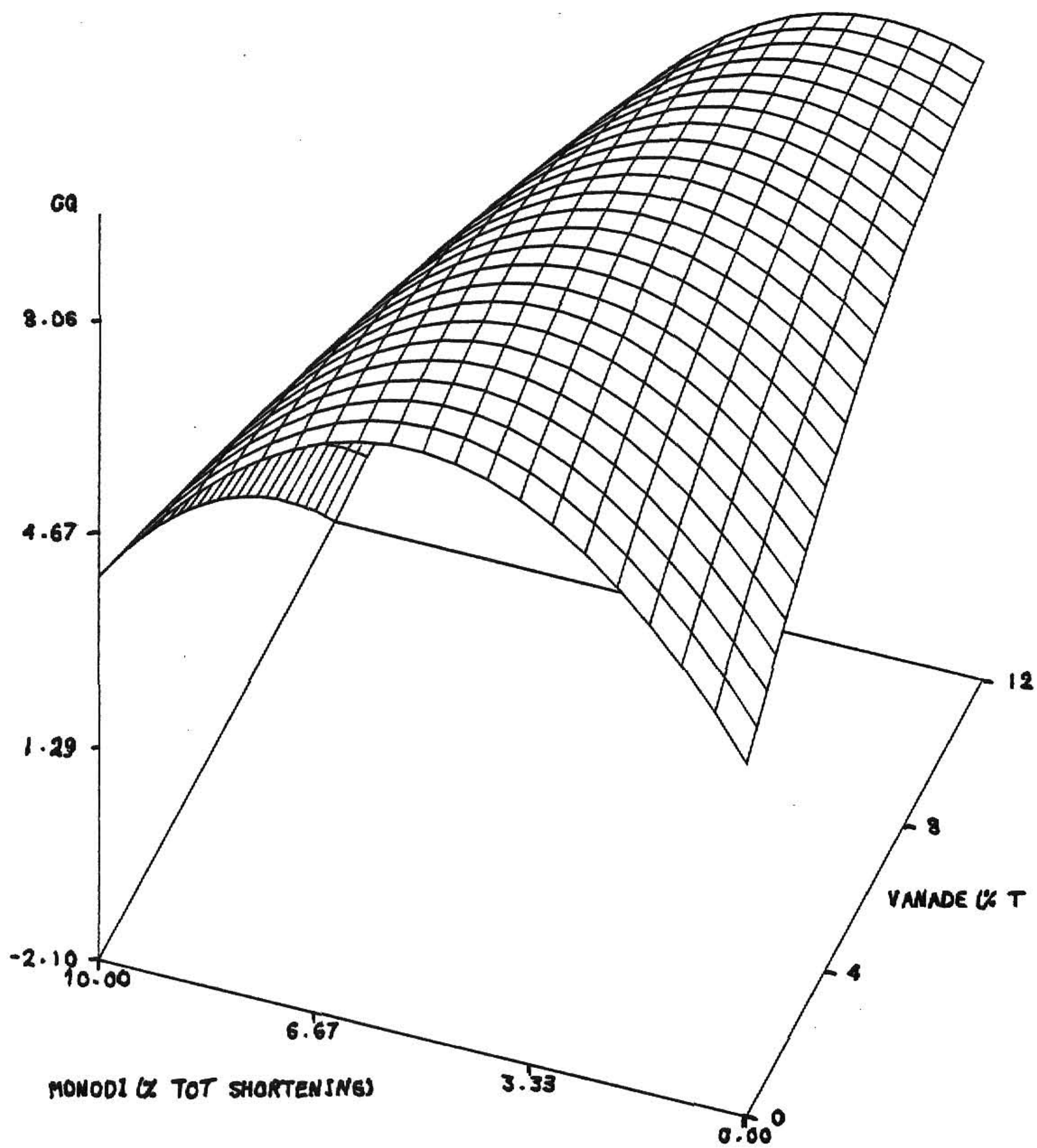


Fig. 20. Three-dimensional response surface of cake grain quality (units) for straight grade flour (MMD = 19 μ, once reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR STRAIGHT GRADE FLOUR
MASS MEDIAN DIAMETER=19

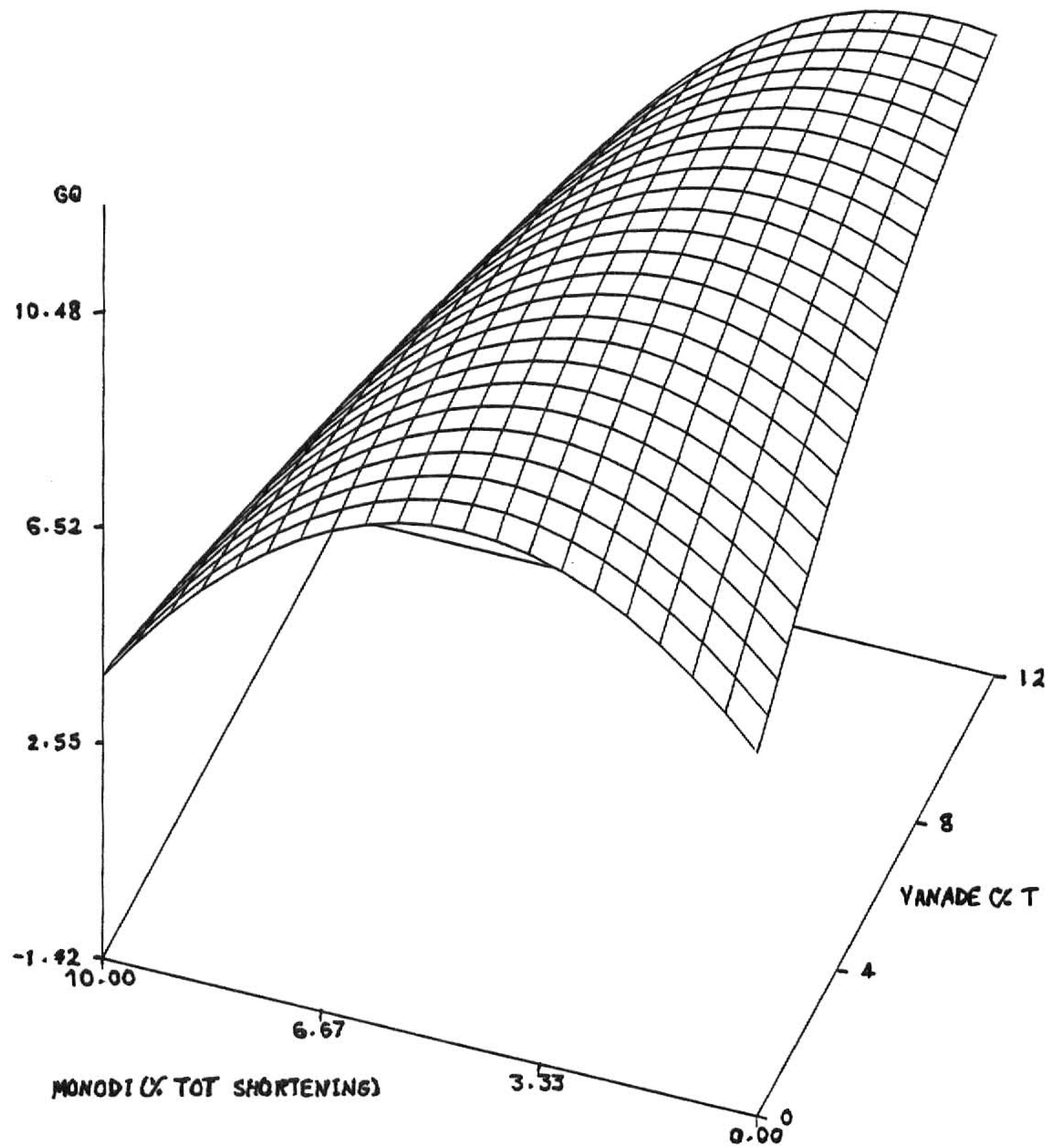
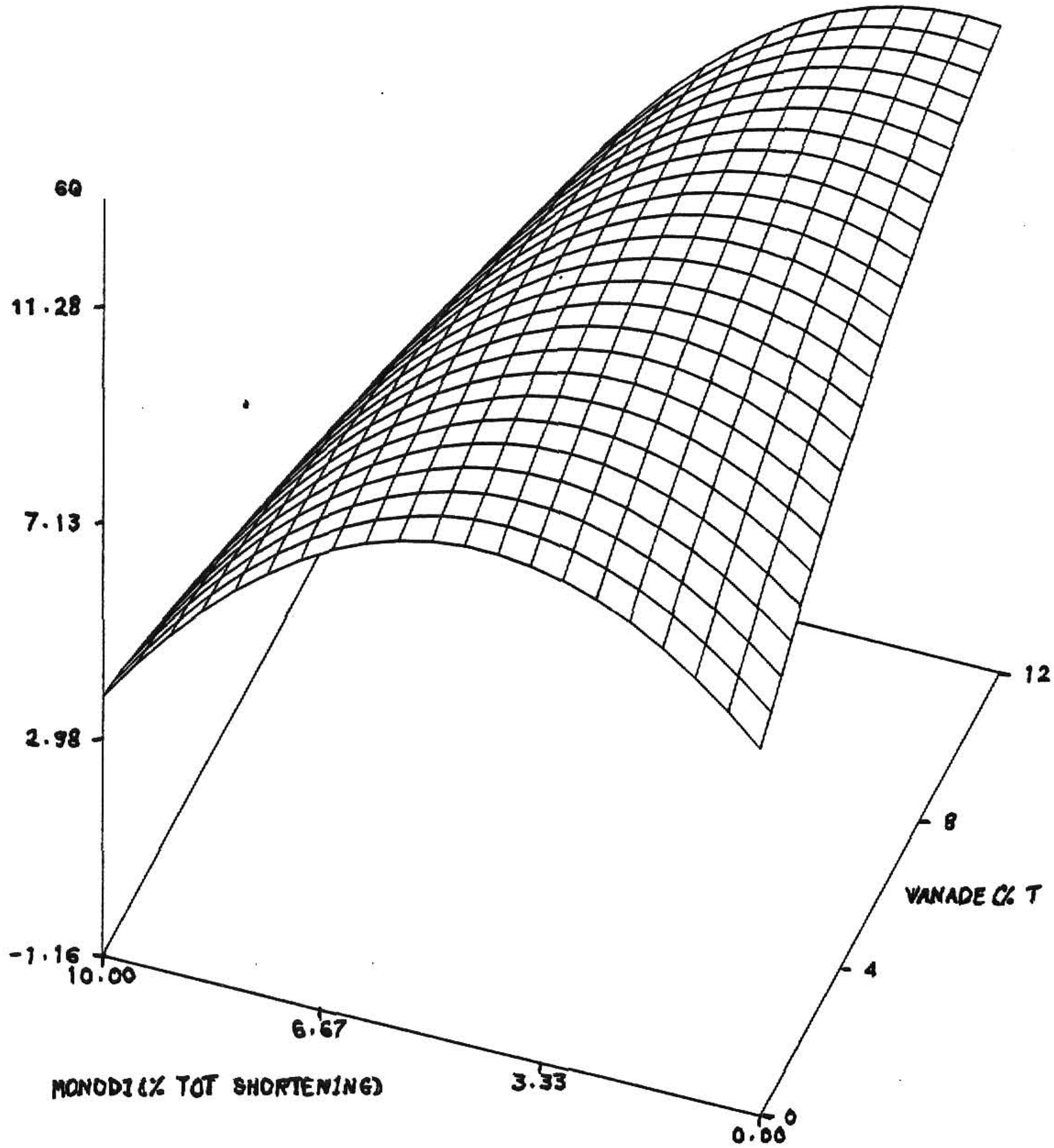


Fig. 21. Three-dimensional response surface of cake grain quality (units) for straight grade flour (MMD = 17 μ, twice reduced) as a function of Monodi and Vanade.

CAKE GRAIN QUALITY FOR STRAIGHT GRADE FLOUR

MASS MEDIAN DIAMETER=17



CONCLUSIONS

On the basis of a response surface study, it was found that reduction in average particle size of cake flour by passing twice through an Alpine mill, and a combination of 5.0% mono- and diglycerides and 6.1% Vanade (on total shortening basis) gave the highest cake quality scores for short patent, middle patent and straight grade flours. Short patent flour yielded superior cakes to middle patent and straight grade flours. The middle patent and straight grade flours are characterized by higher levels of ash, protein, and presumably other materials such as pentosans, that are richer in the lower grade mill streams utilized in these flours. These components are likely a factor in the poorer baking performance of the middle patent and straight grade flours, although the mechanisms involved are not understood.

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EFFECT OF FLOUR PARTICLE SIZE AND EMULSIFIERS ON QUALITY OF CAKES MADE WITH CAKE FLOUR OF VARYING EXTRACTION

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

The objective of this research was to determine the cake making properties of three soft wheat flour of varying extraction: a good quality, short patent flour (ash: 0.34% and protein 9.4%); a poor quality, straight grade flour (ash: 0.47% and protein 10.10%); and a poor quality middle patent flour (ash 0.423% and protein 9.75%). Factors affecting the functionality of these flours such as particle size reduction through the Alpine mill (none, once and twice) and emulsifiers (mono- and diglycerides and Vanade, a water dispersion of 32% sorbitan monostearate and 8% polysorbate 60) were also studied. A method based on the Kissell formula was used to bake the cakes. The quality of cake was determined by its volume, grain quality (fineness, uniformity of cell distribution and moistness by touch), top contour, crumb firmness and crumb color. On the basis of a response surface study, it was found that reduction in average particle size of flour by passage twice through the Alpine mill, and a combination of 5.0% mono- and diglycerides and 6.1% Vanade (on total shortening basis) gave the highest scores on all dependent cake quality responses for the three flours. Middle patent and straight grade flours gave lower cake volume, inferior grain quality, higher crumb firmness and darker crumb color than short patent flour.