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Performance Testing[1]

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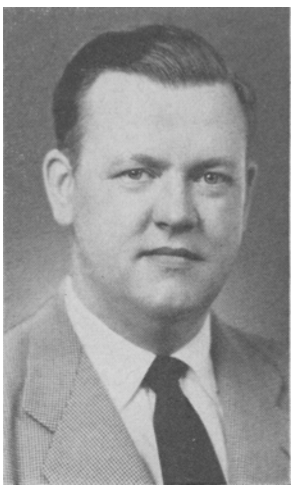
PERFORMANCE TESTING of fats and oils can be considered to be divided into three basic categories: handling, quality, and stability. Although this discussion will refer primarily to the field of dry mixes, it will be seen that the considerations involved could be generalized to include other phases of the shortening industry. Since the third category, stability, is discussed thoroughly in another paper in this series, only the first two categories will be discussed here.



E. C. Swanson

In the category of handling performance, plastic range is quite important in the light of present practical technology. With improved technology and development of present knowledge it is quite likely that plastic range may not be so important in the future as it is today. The plastic range governs the ease with which the shortening is blended with the other dry ingredients of the mix. Every organization has set up its own definite temperature limits within which the various shortenings may vary. The methods of measuring these temperature limits are discussed adequately in other papers in this series.

Votation is responsible for the physical condition of the shortening which, in turn, affects the ease with which the shortening can be incorporated into a mix. Physical condition, within reasonable limits, does not appear to be a significant factor after the shortening has been incorporated into the mix. Texture of the shortening becomes important chiefly when excessive graininess occurs. Graininess obviously exerts a marked influence on the uniformity of the mix.

Another generally used criterion of handling performance is the penetration test. Penetrometer readings however are quite meaningless unless they are correlated with dilatometer measurements. For example, two shortenings which exhibit identical penetration values may contain widely differing amounts of liquid fat. Such differences are important to product quality under given manufacturing conditions. Although processing conditions can be adjusted for various liquid oil levels, obviously such variations affect the routine of processing control.

Because of the tediousness of dilatometric measurements such tests are not readily adaptable to rapid routine control although the testing can be accelerated by setting up a variety of baths. In order to use penetration data in their most reliable form a "grease absorption" test is being developed for the determination of the liquid content of shortenings based on the capillary action of the liquid oil.

With reference to the second phase of performance testing, quality, there are analytical tests galore. Only those which are most readily adaptable to rapid routine control, particularly with reference to the field of dry mixes, will be discussed.

An important test of the quality of a shortening is its water-emulsifying ability. In this test water is dripped from a burette into a standardized amount of fat during mixing in standard mixing equipment. This gives a measure of the "emulsifiability" of the shortening. The greater the amount of water incorporated before the emulsion "breaks," the greater is the emulsifying power of the shortening.

Although shortenings generally contain relatively little water, the analysis of the moisture content serves as an analytical check on the quality of the product.

The determination of free fatty acid is an important test of the quality of shortening, irrespective of the reason for any occurrence of high free fatty acid

[1] Edited by C. W. Hoerr from tape recording of oral presentation by the author.

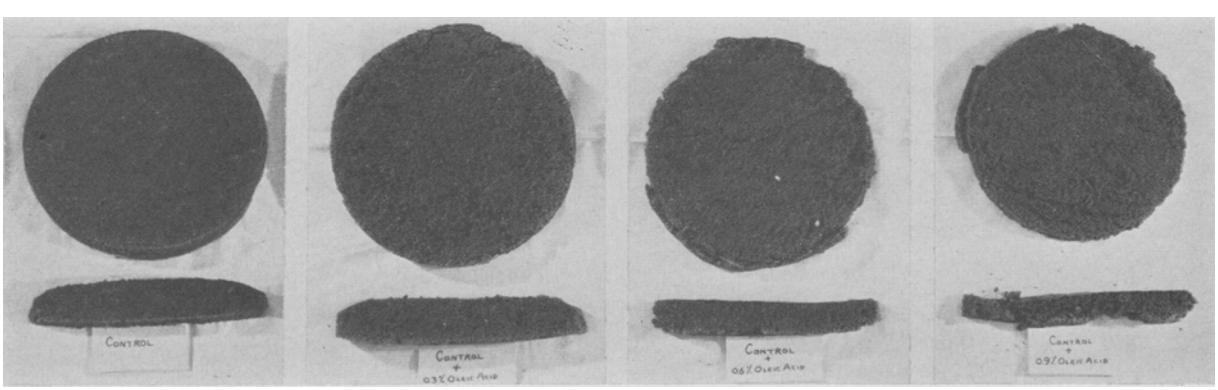


FIG. 1. The effect of 0, 0.3, 0.6, 0.9% oleic acid added as free fatty acid to chocolate cake mix (left to right).

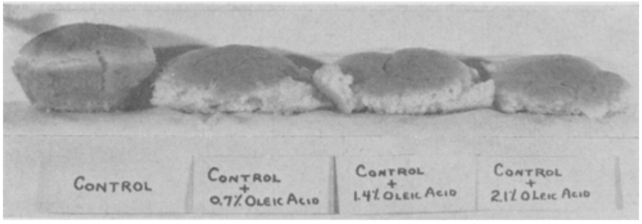


FIG. 2. The effect of 0, 0.7, 1.4, 2.1% oleic acid added to a hot roll mix (left to right).

content. The detrimental effect of this factor on baked goods is shown in Figures 1 and 2. Excessive "tunneling" (this is but one factor responsible for tunneling) and markedly decreased volumes are characteristic of a high free fatty acid content of the shortening.

Baking tests are the physical manifestation of the actual performance of a shortening. It should be borne in mind that the baking test is valid only at the point in time at which the test was applied. The importance of this direct evaluation of a product is obvious. A shortening however should be evaluated in the type of baked product in which it is intended to be used. A common mistake is that of attempting to extrapolate the results of the baking performance of a shortening in a formula for which it was never intended. It is utterly impossible to evaluate the performance of a shortening in a layer cake mix on the basis of its performance in a cookie formula or a hot roll recipe. Figure 3 shows the effect of using the wrong shortening in three types of layer cakes. In each case the normal cakes were made with shortenings possessing the proper emulsifying power for the respective formulas. The cakes at A contained excessive amounts of emulsifier, and the cakes at B were deficient in emulsifier. Differences in cake volume, texture, crust characteristics, etc., can be attributed in these instances to the use of improper shortenings.

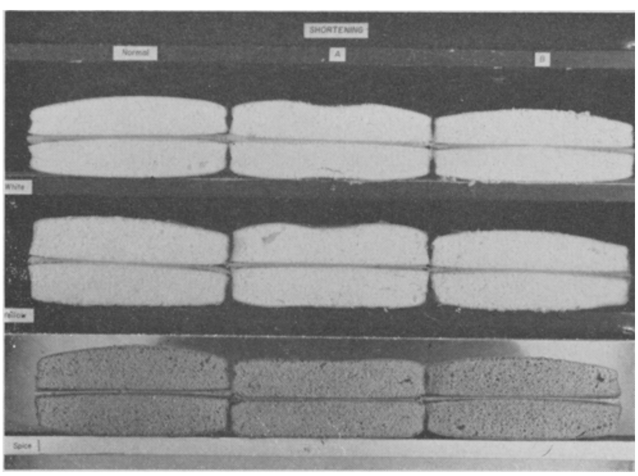


FIG. 3. The effect of employing the wrong shortenings in three types of layer cake mix. Cakes at A contained excessive amounts of emulsifier, and those at B were deficient in emulsifier. White, yellow, and spice cake mix, top to bottom.

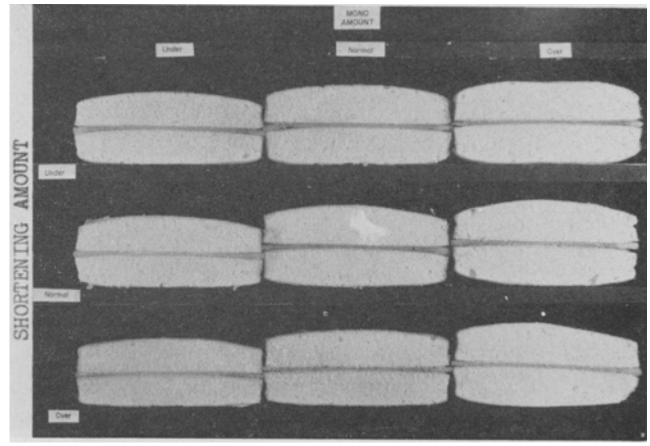


FIG. 4. The effect of varying both the amount of shortening in white layer cake and the amount of mono-glyceride in the shortening.

The characteristics evaluated by the baking tests can be divided into objective measurements and subjective observations. Among objective measurements are volume and symmetry. Numerous methods of measuring volume have been devised. All arrive at reasonably factual results. Although not quite so simple, symmetry can be determined by placing the cut half of a cake against a gauge and measuring the height at the edge and at several points across the top. Attempts to devise an equation whereby an in-

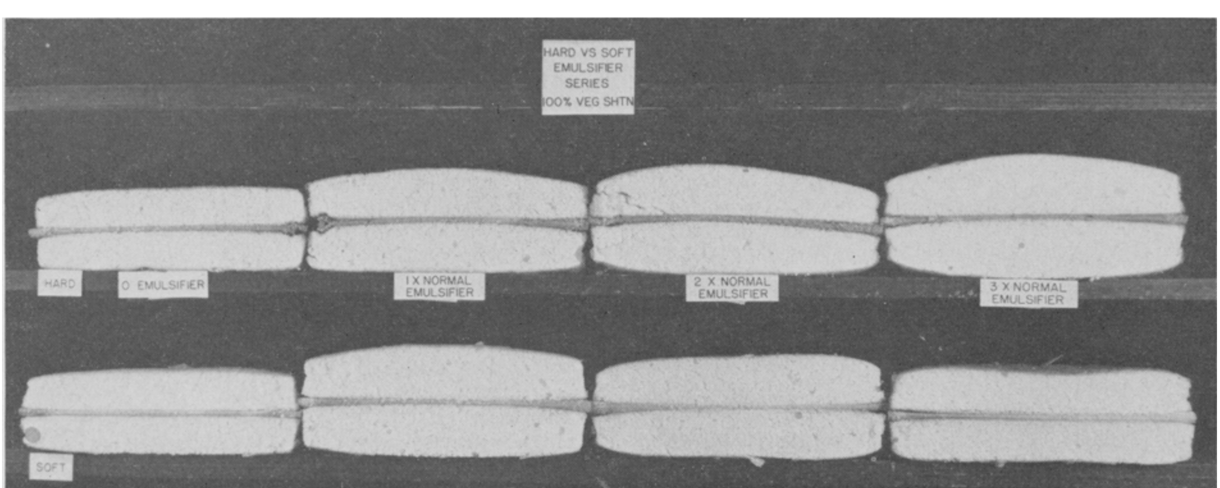


FIG. 5. The effect of 0, normal, twice normal, three times normal amounts of emulsifier in 100% vegetable shortening (left to right). Hard emulsifier on top row, soft emulsifier on bottom.

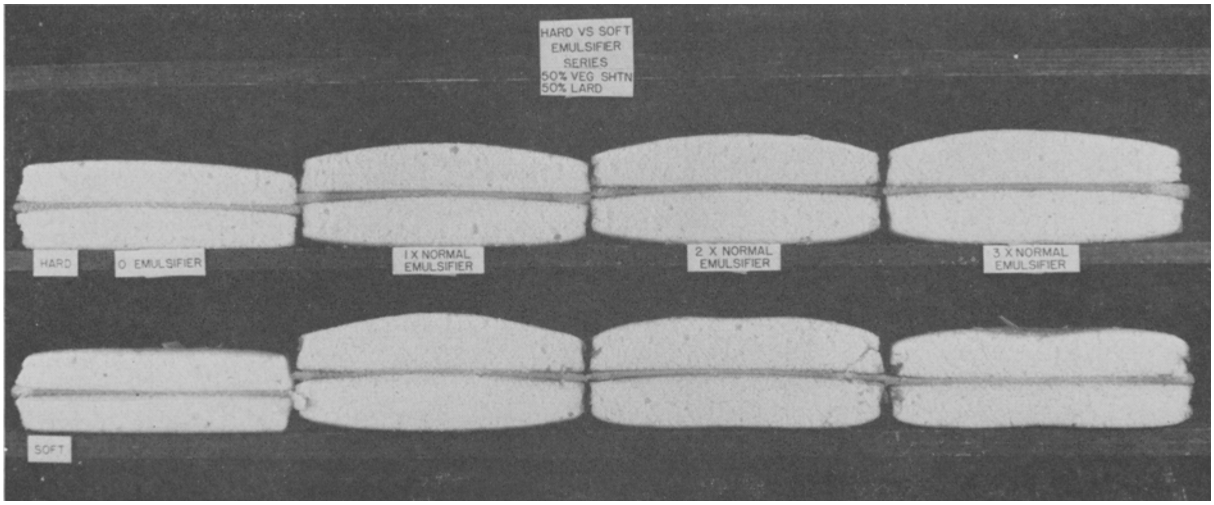


FIG. 6. The effect of various amounts of hard and soft emulsifiers in 50-50 mixtures of vegetable shortening and lard, same arrangement as Figure 5.

dex of symmetry can be obtained from such measurements have not been successful.

Despite efforts to the contrary, observations which still remain largely subjective are cell structure, grain characteristics, texture, wall thickness, and resiliency of the baked product. These properties are related to the "eating sensation" and are subject to personal preferences.

Crust character is another subjective observation as yet not satisfactorily measurable by objective methods. Crusts which are too sugary, too moist, or too dry will be difficult to ice and difficult to cut.

The elusive characteristics of flavor and aroma are other subjective phenomena. These properties are closely associated with the texture of the baked product. A cellular structure which is too fine-grained and thin-walled possesses an excessively large surface area per unit volume. Such a structure absorbs or loses moisture exceedingly rapidly. Consequently, when eaten, the product gives the sensation of being

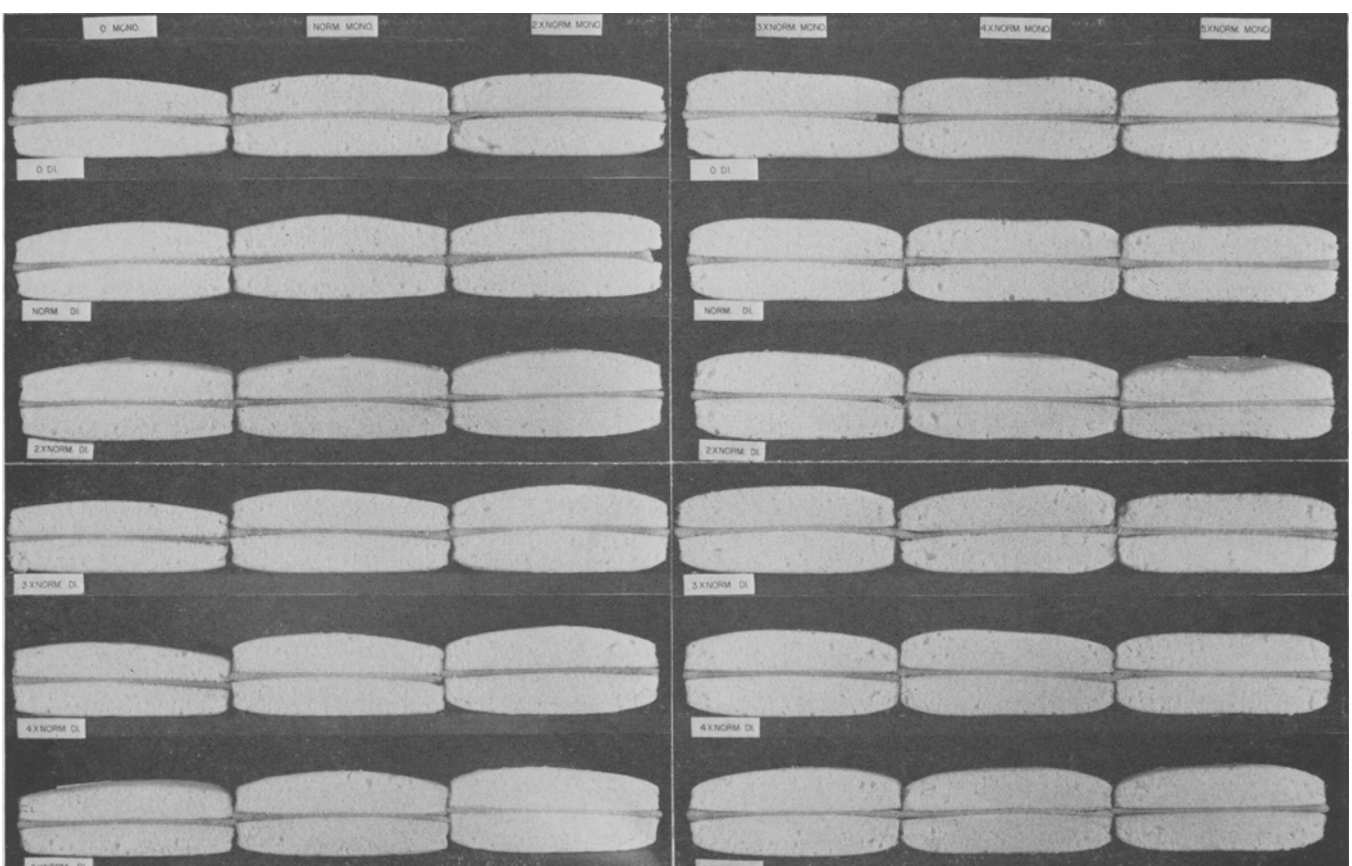


FIG. 7. The effects of various proportions of mono- and diglycerides in standard white layer cake formula. From left to right, 0, normal, 2x, 3x, 4x, and 5x normal amounts of mono. From top to bottom, 0, normal, 2x, 3x, 4x, and 5x normal diglycerides.

sticky, gummy, gluey, or dry, depending upon personal reaction. A structure which is too coarse-grained and thick-walled gives a harsh, sandy sensation in the mouth.

The baking performance test enables the consistent control of product uniformity. It serves to detect variations or errors in any of the manufacturing procedures, such as the compounding of shortenings, processing of other ingredients, formulation of mixes, etc. For example, Figure 4 shows the effect of variations in the amount of shortening in a white layer cake formula, and of deviations in the monoglyceride content of the shortening. It will be noted that, to some extent at least, the effects of abnormal amounts of emulsifier can be corrected by appropriate variation in the amount of shortening incorporated in the mix.

In addition to serving as a check on the uniformity of manufacturing procedures, baking tests are also useful as a research tool for determining proper formulation of ingredients. For example, Figures 5 and 6 illustrate the results of tests on emulsifier composition. By varying the amounts of hard and soft emulsifiers, *i.e.*, those of relatively lower and higher iodine values, layer cakes of different volumes and textures were obtained. Baking performance tests permitted the selection of the proper blend of hard and soft emulsifiers possessing an average iodine value which produced the desired results. (A single emulsifier with the same iodine value as the blend average would not work as well.)

Another interesting phenomenon demonstrated by baking performance tests is shown in Figure 7. This series of photographs illustrates the interrelated effects of mono- and diglyceride emulsifier composition on layer cake quality. It can be seen that neither the mono- nor the diglyceride alone yield the proper degree of emulsification. Tests such as these have demonstrated that a certain proportion of each is necessary to produce the desired cake volume and texture.

X-Ray Spectroscopy

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SPECTROSCOPY is a means of determining certain properties of materials by utilizing the effects produced by applied energy of various wavelengths. Based upon the wavelength of the energy employed, spectroscopy is divided into several fields. One of these main divisions is x-ray spectroscopy, in which x-rays are employed as the source of energy for bombarding the material under analysis. X-ray spectroscopy can be subdivided in the same manner as is ultraviolet or infrared spectroscopy. Thus x-ray absorption is possible because some materials absorb x-rays more strongly than do other materials. In x-ray fluorescence, matter which is excited by x-rays will alter the primary wavelength. In x-ray diffraction the direction of the primary wave is changed by the material, but its wavelength is unchanged. The techniques of these subdivisions of x-ray spectroscopy may be applied at one time or another to numerous classes of materials. However when applied to the field of fats and oils, x-ray diffraction is by far the most utilized application. The wavelength of the primary wave remains unchanged in diffraction. By means of diffraction it is possible to determine crystalline structure, and the molecular dimensions of crystalline substances. Crystal structure in general will be treated briefly in order to lend understanding to the usual habit of long chain compounds under normal conditions. The major concern of this paper is that phase of crystal structure having to do with polymorphism, and it reports the development, application, and interpretation of x-ray diffraction patterns as an analytical method of determining polymorphism and changes in polymorphic phases in fats, fatty acids, and derivatives.

W. S. Singleton

The economic aspects of polymorphism in fats and products derived therefrom should be mentioned briefly. The manipulation of fatty materials to obtain the desired polymorphic forms and to prevent subsequent changes to undesirable forms requires considerable effort on the part of manufacturers. In the processing of shortening and margarine, equipment is designed and operated so as carefully to control the temperature levels and rate of cooling during plasticization, packaging, and subsequent tempering. Some of these operations also serve, of course, to control crystal size. In candy-making the temperature and rate of cooling of chocolates and fat-containing coatings is carefully controlled.

In certain instances the need of a given polymorphic form of a product is functional. For example, the melting point of a given fat can vary many degrees depending upon its polymorphic form. In soap-making precautions are taken to obtain certain polymorphic forms as polymorphism has a decided influence upon the hardness and the lathering properties of soap.

In other instances polymorphism is important because of its effect on appearance. Partial melting of a low-melting form in shortening or margarine followed by resolidification to a higher melting form destroys the smooth texture of the product and produces instead a grainy appearance. Polymorphic changes in candy fats produce "bloom," dullness, and possibly other faults, which can harm the reputation and competitive position of the manufacturer.

Equipment for X-ray Diffraction

The source of x-rays for obtaining x-ray diffraction patterns will not be discussed in detail since excellent

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