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PRELIMINARY STUDIES ON APPLICATION OF OBJECTIVE TESTS TO TEXTURE OF FRENCH FRIED POTATOES[1,2]

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Potatoes exceed all other vegetable crops in total production. Each year there has been an increase in the percentage of the total crop processed as French fried potatoes and this increase has led to an increasing number of control problems. Some of these problems have concerned color, flavor, appearance, fat content, and texture. This paper is concerned only with the textural problem.

Many factors have been suggested to which texture characteristics can be attributed but these observations are of value only in a general way since, when a crop is harvested and purchased by a processor, the future quality of the product has largely been established. Treatments such as precooking and cooling (2), chemical additions (4,5), etc. may be employed to modify quality to a certain extent by some chemical and/or physical objective test is needed to predict quality and, possibly, to predict treatments necessary for modifications.

Objective textural methods are designed to measure the usual characteristics which are responsible for consumer reaction to a product. Of the objective methods available for measuring texture, such as cutting force, compression, tensile strength, and shear, it was thought that shear measurements would have the greatest applicability to French fries, although it is known that it is practically impossible to obtain shearing without some compression. It has recently been shown that the exact proportion of shear to compression can be calculated. With different sized blades, the shear is proportional to the perimeters while compression is proportional to the areas (1). These relationships may later be of value to French fry texture measurements after quantitation studies have been completed.

In any new application of techniques such as this, interpretation of the curves is required before any definite recommendations can be made. The experimental work in this paper is directed entirely at this problem.

Materials and Methods

The L.E.E.-Kramer Shear Press (Model SP 46) with Allo automatic recording of the force variations during the shearing tests (Model R1E) was selected for these studies.[4] In early phases of the investigations it was observed that, at low sensitivity settings of recorders, certain events in the recorded curve were missed. As a result, the damping control of the Allo recorder was set at such a position that the sensitivity was just under the point where noise would influence the recorded results.

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[4]Mention of company or trade names does not imply endorsement by the Department of Agriculture over others not named.

This position is in the upper range of the damping capacity because, as we were recently informed (3), the Allo Company had inadvertently built in what they consider to be a condition of overshooting. At this sensitivity setting, there is some overshooting of the recorder when a rapid change of pressure is recorded but this only tends to exaggerate certain occurrences which may well have been missed at higher instrument damping levels. After this experimental work was complete, the new Allo Model E2EZ amplifier was obtained and, even at maximum damping, similar multiple peak curves were obtained.

The piston speed employed was 0.12 inches per second. Two sensitivities were used depending upon the force required to shear the product. One sensitivity gave 300 pounds for full scale deflection, the other gave 1000 pounds (designated 300R and 1000R in the figures). The shearing cell was the standard Kramer Shear-Compression cell, with 10 blades, ⅛ inch wide, and having 90° angles. The transducer and shearing cell were attached to a 3000 pound proving ring. Due to the method of driving the chart paper all curves produced begin at the right and end at the left.

Katahdin potatoes, of as near similar characteristics as possible to obtain, were employed throughout the experiments. French fry slices, ⅜ inch by ⅜ inch by 2⅝ inch were used in all but one case. The frying temperature was 365 F. No blanching was included.

Results and Discussion

In Fig. 1 is depicted a typical French fry shear curve. Since shear cannot take place without compression, it can be assumed that the curve must rise as the compression increases. However, the curve for a French fried strip shows three points of inflection (B, C, and D) and that for a fresh strip shows two inflections (B and C). The question now arises as to which of these peaks is due to shear and what causes the other two peaks. In addition, the question as to whether the peaks for fresh and fried samples are due to the same events is of importance.

Fig. 2 is a series of curves produced from measurements of French fry slices fried for different lengths of time and sheared immediately after removal from the hot fat. To facilitate comparisons, each individual shear curve was placed at equal distances along the time axis. Zero time is, of course, the fresh unfried slice. The time of frying at 365 F increases from right to left. The peaks marked by stars increase with frying time as do those with filled circles. Those peaks marked by open circles and by triangles decrease with frying time. The identity of these peaks and their importance will be discussed later in relation to the other experiments.

The shape of the curve and the information obtainable with both fresh and fried slices is affected by the method of introducing the samples into the test cell, as shown in Fig. 3. In this early experiment, slices measuring ½ x ½ x 2⅝ inches were used. Multiple layers or random introduction produces amorphous type curves due to several events occurring simultaneously. One slice produces a curve in the correct range but it is relatively small both in height and area. Five slices in one layer (which just fills the cell) gives the same information but is better because of the relatively larger size. Seven slices measuring ⅜ x ⅜ x 2⅝ inches

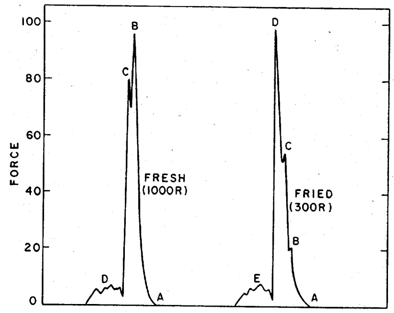

FIG 1

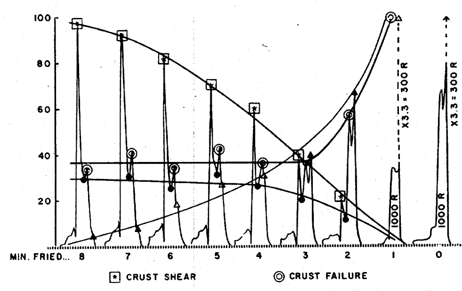

FIG 2

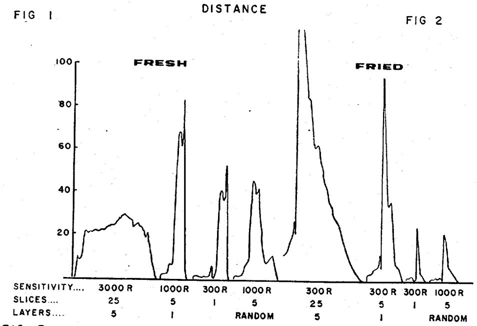

FIG 3

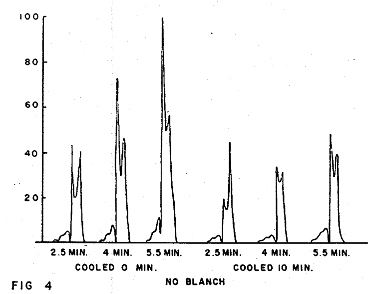

FIG 4

FIG. 1.—Sample shear press recordings for fresh and processed French fried strips.

FIG. 2.—Relationship of time of frying to shear press results.

FIG. 3.—Effect of method introduction of sample in the shear press cell.

FIG. 4.—Effect of frying time and cooling on shear press results.

gives the same result. This latter method was chosen as the most informative.

Fig. 4 again shows the effect of frying time. It can be seen that on the first three curves from the left, one peak increases with increased frying time. These samples were sheared immediately after frying. If allowed to cool for ten minutes before measuring, the left peak still increases with frying time but the total force required is lower. This indicates a redistribution of moisture in the pieces, causing a softening of the crust and a resultant lower shear value.

Since it is impossible to see through the shearing cell walls to observe what events occur, a model shear press, shown in Fig. 5, was constructed. The upper set of blades are driven downward by means of the screw and handle. Although the blades are ⅜ inch wide, as compared to the ⅛ inch blades in the Allo-Kramer Shear Press, the events occurring can be seen and photographed. By use of a rapid-firing camera, the shearing of fresh and fried strips was recorded and those pictures which were thought to indicate the points of inflection on the shear curve were selected. Fig. 6 describes the results with fresh potatoes. At Point A, the cell structure resistance was at a maximum. The decrease in pressure to Point B is believed to be a measure of the firmness of the potato

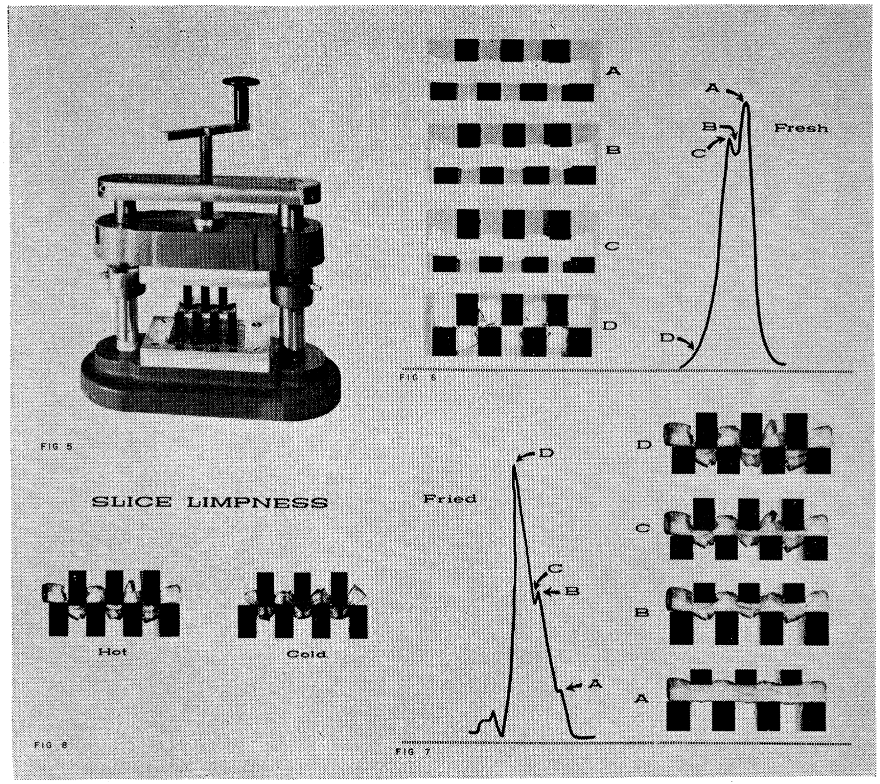

FIG. 5.—Model shear press.
FIG. 6.—Sequence of events during shearing of fresh French fry strips.
FIG. 7.—Sequence of events during shearing of processed French fry strips.
FIG. 8.—Reaction of hot and cold French fried slices to shearing.

tissue. With continued lowering of the blades, the tissue was again compressed to Point C where the tissue began to split and again the back pressure relaxed. A decrease in the curve was assigned to this event. Picture D shows the resulting split tissue. On the basis of these observations, it is believed that no actual shearing occurs in fresh strips.

Fig. 7 shows the results obtained with a French fry strip sheared while hot. Point A was assigned as the result of cell rupture. The pressure again built up to Point B where the crust actually began to break and the inner contents flowed out. At the point where the upper and lower crusts came together and were sheared by the blades (D), a maximum would be obtained. Any changes in pressure after the blades mesh would be due to the viscosity or graininess of the product which makes the blades stick together and produce slight variations.

Fig. 8 shows the effect of slice temperature upon the sheared slices obtained with the Model Shear Press. A slice sheared while hot is cut cleanly. A cold slice is soggy and tends to bend and lift from the blade surfaces.

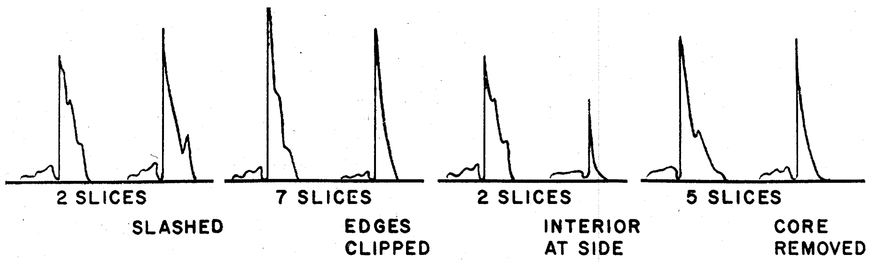

FIG. 9.—Effect of altering of slice to shear results.

To establish definitely the cause of each peak and verify the observations described above, a set of experiments, shown in Figure 9, was set up. The two curves on the left are each the result of shearing two fried slices in the Allo-Kramer shear cell. The left is the normal curve; the right is the result of slashing all four long faces. The second peak (crust failure and flow of inner contents) was eliminated. The second set of curves are the normal shear and the shear obtained when the four long corners were clipped off with scissors. As a result both the first (initial cell rupture) and the second peak were eliminated. The third pair of curves resulted from dissecting the slice to remove the inner contents which were placed beside the hollow crusts. Again both peaks disappeared. The fourth set shows the result of removing the interiors from five slices and shearing the crusts without the contents. Since only the crusts were sheared, the remaining peak is then due to this event. These experiments indicate that the intact crust has something to do with the first two peaks and that the inner contents also play a part but only when they are enveloped by the crust.

From the preceding experiments, the results shown in Fig. 2 are more significant. The starred peaks increase with frying time and are due to the crispness of the outer crust. The filled circles representing valley depths, are probably due to the fluidity of the inner contents. As frying time is increased, more and more water is eliminated from the inner cell tissue and, being dryer, the back pressure increases. At the same time the outer crust becomes more impervious and water escapes from the inner contents with greater difficulty. As a result the curve levels off.

Those peaks marked by open circles are due to crust failure. As the potato slice is fried, the crust is made more friable and the pressure required to cause breaks in the crust decreases until a constant value is obtained. The peaks marked by triangles are due to initial cell rupture. As the slice is cooked for a longer and longer time, the tissue becomes softer and more easily broken apart and compression is continuous until the outer crust breaks.

Questions now arise as to what may come out of these experiments and what must be done in the future. With the exception of the frying time experiments, no attempt to develop information on the quantitative aspects has been made. Further research is necessary to develop the quantitative relationships between the several peaks. It is also necessary to make quantitative studies on potatoes of different varieties, sources, subjecive qualities, and from different storage conditions and periods, to develop the relationship between fresh quality and processed quality and, also, between fresh fried and frozen and stored products.

The problems involved in quantitation are not easily solved because of the nature of the curves produced. However, certain facts are available which can be used. Since the X axis of the shear curves represents the distance or ram travel at constant ram speed, and the Y axis represents the force of shearing, the area under the curve then represents the work performed. The problem then resolves itself into the actual measurement of the areas. Planimeters are difficult and tedious to use and, inherently, are not capable of producing the accuracy required. Integration of peak areas by electronic integrators has been tried with some success but, since the entire operation requires only about four seconds for the informative section, speed of integration is a problem. Use of slower ram speeds may partially or completely eliminate this problem if too many other problems are not developed. Modification of the methods of collecting data, storing it and finally integrating at a more reasonable rate are possible and are presently under investigation.

Summary

A commercial shear press with electronic recording was used in a qualitative study of the shearing of French fried potatoes. Typical curves were presented and experiments were described to determine the relationships of events depicted in those curves with actual changes in the test material. Three peaks were observed in the curves for the fried product which were due to cell failure, cracking or fracture of the outer crust and shearing of the two layers of crust after they had been compressed together. It was suggested that no actual shearing occurs in fresh potatoes during the test operation.

Resumen

Una prensa-cortadora comercial con una grabadora electrónica ha sido empleada en el estudio cualitativo del corte de papas a la francesa. Gráficas típicas han sido dadas y experimentos descritos para deteminar las correlaciones entre las gráficas dadas y los cambios ocurridos en el material de ensayo. Para el producto frito se han observado tres picos en las fráficas que eran debidos al colapso celular, rajadura o ruptura de la costra y a la cortadura de las dos capas de costra cuando éstas habían sido comprimidas. Parece que durante el ensayo con papas frescas una verdadura cortadura no tiene lugar.

Acknowledgment

The authors wish to acknowledge the competent help of Mr. Robert Bram in the construction of the model shear press, of Mr. Eugene Kordwitz in the preparation of the figure drawings, and of Mr. M. C. Audsley in the preparation of the photographs.

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