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TEXTURAL PROPERTIES OF PLANT PROTEIN MODEL SYSTEMS

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ABSTRACT

The effect that solids concentration and protein source had on the textural properties of cooked plant protein model systems was studied by evaluating four solids concentrations of fababean, pea and rapeseed protein concentrates. Two starch samples, corn and amioca, were also evaluated to assess which textural parameters were related to protein and which were related to carbohydrate. The effect protein level had on texture was also examined by evaluating four protein levels (7, 30, 50 and 70%) of fababean and wheat flours. Each protein level was examined at four solids concentrations. Samples were cooked, cooled overnight and served at room temperature. A six member trained panel judged the intensity of eight texture parameters including viscosity, stickiness, mouthcoat, slipperiness, dryness, particle size, wateriness and cohesiveness, using the method of magnitude estimation. Viscosity was the only parameter perceived in all treatments. The parameters found to be related to protein samples included mouthcoat, stickiness, dryness and slipperiness. Parameters related to carbohydrate samples included slipperiness, cohesiveness and wateriness. Differences in the parameters perceived in each treatment were also found to exist. Slipperiness could be perceived in fababean concentrate but could not be perceived in rapeseed and pea concentrates. Only those treatments following a linear function were used for treatment comparison. If a significant relationship was not found, it is possible that the parameter could not be perceived or the concentration range examined for each treatment was too narrow to permit intensity differences to exist. Where a significant relationship was found, the growth of the perceived parameter over solids concentration could be defined by the power function $S=kC^n$. For treatments which had a significant relationship, the perception of slipperiness and wateriness was found to decrease as solids concentration increased, whereas for the other texture parameters, the perceived intensity was found to increase as solids concentration increased. An increase in protein level was found to decrease the perception of viscosity, mouthcoat, stickiness, slipperiness and wateriness. The effect protein level had on dryness, cohesiveness and particle size could not be determined. Flow properties of all treatments were assessed using the Brookfield LVT viscometer. Apparent viscosity was found to relate directly with increasing solids concentration but inversely with increasing protein level. Treatments were found to be different in their shear thinning behavior. Rapeseed, corn, 7% fababean protein and 70% wheat protein were more affected by shear rate than treatments such as amioca, 70% fababean protein and 30% wheat protein. High correlations were found between perceived viscosity and instrumental viscosity making it possible to use the power function $S=kP^n$ to predict sensory response on the basis of instrumental findings. Mouthcoat was found to correlate well with apparent viscosity but no relationship could be established between apparent viscosity and stickiness.

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INTRODUCTION

Plant proteins are of increasing interest to the food technologist as the need to develop new protein resources continues to grow. Legumes and oilseeds offer the greatest potential as additional protein sources in terms of economics, technology, processing and acceptability in comparison to fish, leaf and single cell protein (Anon., 1970).

At present, soybean serves as the major source of high quality plant protein. Not only has soybean become an important food protein supplement, but it has become the main ingredient in many food products. Extensive research on the nutritional and functional properties of soybean protein has resulted. Desirable functional properties found in soybean include emulsification, fat absorption, moisture holding, thickening and foaming. Soybeans, however, are not without their limitations in food application and additional sources of plant proteins would provide a desirable range in both functional and nutritional characteristics (Fan et al., 1974). In addition, the utilization of plant proteins is expected to increase and has been predicted to replace one half to two thirds of our food grade protein within the next several decades (Bird, 1974). In order to meet these demands, the production of soybeans and other plant proteins must be expanded. Unfortunately, climatic conditions in Canada are not favourable for large scale production of soybeans. Pulse crops such as fababean, pea and rapeseed are more suited to the colder climate found in Western Canada. Researchers have shown these crops to be good yielding, high in protein and to have functional properties that equal and in some cases, excel those found in soybeans. Through plant breeding and extraction methods, the level of glucosinolates in rapeseed has been reduced to trace levels, permitting rapeseed to be considered a valuable protein source.

Despite the research being carried out to assess the nutritional, chemical and functional properties of novel protein sources, few studies have been undertaken to determine the perceived textural properties of these proteins. Johnson (1970) has emphasized that the only reliable way of determining how a protein will behave in a food is to incorporate it into the formulation and produce the final product, a task which is both time consuming and costly. An understanding then, of the textural properties imparted by plant proteins would be useful in predicting their appropriate uses in food products. Since texture is considered important in food acceptance, a study was initiated to assess the textural properties of plant proteins in a model system.

The major objectives of the study were as follows:

1. To describe the textural properties of several novel plant protein concentrates.
2. To study the effect of increasing solids concentration on the growth of the perceived intensity of each parameter.
3. To study which textural parameters are related to protein and which are related to the carbohydrate fraction.

4. To study the effect of increasing protein level on the perception of textural parameters.

5. To assess if instrumental measurements of viscosity can be correlated and used for prediction of sensory responses to one or more textural parameters.

REVIEW OF LITERATURE

Rheological Properties of Texture

Rheology is defined as the study of deformation or flow of a material under stress. During mastication, deformation of a food by stress applied by the teeth or tongue is only one of a number of processes occurring. Other processes include the reduction in the size of a food and the mixing and hydration of the food with saliva (Bourne, 1975). Thus, rheology cannot provide all the answers to food texture characterization, but it does offer a fundamental, sound approach to the characterization of basic properties (Szczesniak, 1977).

The assessment of the rheological properties of a material is made somewhat complicated by the fact that most foods are neither entirely solid nor truly fluid, but instead possess rheological properties of both states of matter. Basically however, fluids and semi-solid foods such as cooked pastes and gels can be classified as either Newtonian or non-Newtonian systems. Newtonian fluids flow at a steady rate or have a constant viscosity that is independent of shear rate. Foods such as cooking oils, corn syrup, and dilute beverages exhibit Newtonian behavior (Muller, 1973).

Most foods however, are non-Newtonian and are therefore, dependent on shear rate. Pseudoplastic flow represents one type of non-Newtonian behavior that is exhibited by cooked starch, (Szczesniak _et al_., 1962) and protein pastes (Circle _et al_., 1964; Hermansson,1975). Pseudoplastic fluids become less viscous as shear rates increase. A more detailed discussion of Newtonian and non-Newtonian fluids has been presented by Muller (1973).

Components That Influence Texture

a) Hydrocolloids

The importance of hydrocolloids in food products is based on the hydrophilic properties of the hydrocolloid which affects the food structure, texture and related functional properties (Kose *et al.*, 1972). Hydrocolloids are polymeric materials that can be dissolved or dispersed in water to give a thickening or gelling effect (Kose *et al.*, 1972). Starch is only one of the hydrocolloids that may be found in plants and is in fact, found in corn, wheat (McNicol *et al.*, 1972) fababean and pea (Cerning-Beroard *et al.*, 1976). Other polysaccarides (arabinan, amyloid, acidic arabinogalactan) have been identified in rapeseed (Siddique *et al.*, 1974).

Two basic types of polymers are present in most starches, these being amylose and amylopectin. They differ not only in size and shape but in the way the basic monomeric units are linked together. Amylose is a linear polymer containing hydroxyl groups which are responsible for imparting the hydrophilic properties to the polymer. There is a tendency for these molecules to become orientated parallel to one another and through hydrogen bonding, form aggregates that are insoluble in water. In dilute solutions, the aggregate precipitate whereas in more concentrated solutions, a gel will form (Wurtzberg, 1972).

In contrast, amylopectin is a highly branched polymer. The mobility of the molecule is limited by the branches and therefore, orientation with other molecules cannot occur. As a result, pastes made from amylopectin starch have a resistance to gelling (Wurtzberg, 1972). One such starch, amioca, a genetically modified corn starch, was included for evaluation in the study.

Modification of characteristics governing starch properties can be done by a variety of techniques. One such technique is by cross-linking. Cross-linked starches are characterized by a short-salve-like property which upon heating, quickly changes to an elastic and rubbery texture when the swollen granules rupture, forming dispersions of molecular aggregates (Wurtzberg, 1972). Pasting curves of pea starch have shown restricted-swelling characteristics similar to cross-linked starches (Vose, 1977).

Amylose/amylopectin levels are similar for wheat and corn starch with levels of 25/75 and 26/74 found for each, respectively. In comparison, amylose/amylopectin levels of pea and fababean are reported to be 35/65 (McNicol _et_ _al_., 1972).

Sosulski _et_ _al_ (1975) studied the viscosity and gelation properties of ten legume flours. Two of the flours examined contained no starch (soybean, lupine). The range of starch for the remaining flours was from 36.9% to 59.1%. Fababean and pea contained 51.6 and 54.1% starch respectively. In addition, the amylose content of the starches was determined. It was found that the starch content of the flour appeared to be more important than amylose level in determining the viscosity characteristics of cooked legume pastes as determined by a viscoamylograph. Starch did influence the amylograph patterns by showing higher peak and cold viscosities for all flours containing starch in comparison to soybean and lupine flours containing no starch.

McEwen et al (1973) compared the amylograph patterns of fababean and wheat flour. Similar amylograph patterns were found for the two flours except that the peak viscosity and a greater rate of thickening at the 35°C hold period was found for the wheat flour. It was noted however, that the same weight of the two flours was used and therefore, wheat flour contained twice as much starch than did the fababean flour because of the difference in protein quantity. In comparing a starch fraction of fababean with wheat starch, the same authors observed differences in the amylograph patterns. Fababean starch showed a greater viscosity during the initial temperature rise as well as at cold paste viscosity.

A recent study by Vose (1977) compared the starch fraction of pea with corn and wheat starches. The pasting curves of pea starch showed restricted swelling characteristics in comparison to the other two starches. This behavior was considered similar to that of crosslinked modified starches.

To date, few studies have been undertaken to assess the thickening properties of rapeseed carbohydrates. Most attention has been focused on assessing the functional properties of rapeseed protein.

One of the greatest effects on the behavior of starch is the amount of water available to the starch. In sauces, puddings and pastes, where the amount of water present is not a limiting factor, the starch granules swell to an enormous size. However, in limited water systems such as found in bread, the starch and protein fractions are in competition for the limited amount of water available. Although proteins differ in their water holding capacity, Larsen (1964) has shown that wheat starch can absorb water more rapidly than wheat protein (gluten), resulting in insufficient hydration of gluten necessary for bread structure. An unlimited water system was chosen for use in this study.

b) Protein

Advances in technology have made it possible to isolate many of the proteins found in plants. The major protein found in wheat has been identified as glutenin (Dechary et al., 1966), known for its elastic and cohesive properties. Globulin proteins are considered the major proteins in fababean and pea (Fleming et al., 1975) and in rapeseed (Gill et al., 1976).

A study by Fleming et al (1975) examined the thickening and gelation properties of heated dispersion of concentrates and isolates of pea and fababean. In addition, the globulin protein fractions were isolated from pea and fababean concentrates and their gelation ability was evaluated. Concentrates and isolates for both pea and fababean showed similar high viscosities and had medium gels. The 10% protein dispersions of the globulins for both legumes formed thickened gel structures upon heating in a dilute salt solution.

A study by Gill and Tung (1976) examined the rheological properties of isolated globulins from rapeseed. Heating a dispersion of 5.4% protein, resulted in gelation and considerable thickening was observed in a 1% heated protein dispersion.

Thickening and gelation properties are useful in meat systems for fat and moisture holding (Briskey, 1970). The gelling ability exhibited by these proteins suggests their use in the meat industry.

Sensory Evaluation of Texture

Texture has been defined as the composite of those properties which arise from the structural elements of a food and the manner in which these register with the psychological senses (Sherman, 1970). This definition is acceptable to most workers studying texture, since it recognizes three essential elements of texture: (1) texture is a sensory quality; (2) texture stems from the structural parameters of the food (molecular, microscopic, or macroscopic); and (3) texture is a composite of several properties (Szczesniak, 1977). The perception of texture is considered a complex task, involving sense organs found in the tongue, gums and the hard and soft palate. Because texture is so complex, its assessment by sensory evaluation is probably the only means of obtaining reliable information on the texture of a food (Matz, 1962).

Despite attempts by Sherman (1969), Yoshikawa et al (1970), Szczesniak et al (1963^b), Szczesniak (1971) and Jowitt (1974), to describe and give rational meaning to textural parameters, there is no generally accepted glossary of food texture terms.

Szczesniak (1963) proposed a system for classifying the textural characteristics of food based on fundamental rheological principles. This work is the basis for most studies currently being done in this area. Textural characteristics were classified into mechanical and geometric qualities as well as those related to moisture and fat content of the food product. Mechanical properties of food were further divided into primary parameters such as hardness, cohesiveness, viscosity, elasticity and adhesiveness. Secondary parameters included brittleness, chewiness and gumminess.

Further work by Szczesniak et al (1963[a]) resulted in the development of standard rating scales for the sensory evaluation of these parameters. Each point on the scale is represented by a food product and the scales are reported to cover the entire range of texture intensities common in food products.

However, use of category scales has been found to have several limitations. Moskowitz and Sidel (1971) summarized these limitations:

1. The category scale lacks a true zero so that ratios of differences cannot be inferred. The only conclusion possible is that the samples are or are not different.
2. The judgements are biased by the reluctance of judges to use extreme categories at both ends of the scale.
3. The intervals between the categories may be psychologically unequal.

In contrast to category scaling, a method known as magnitude estimation may be used that has been found to compensate for differences among panelists in handling sensory information. It allows each panelist to judge a sample on his own sensory continuim (Moskowitz et al., 1972). The task that is involved is judging the intensity of an attribute in relation to a reference sample that illustrates this attribute. Furthermore, magnitude estimation is considered a simple technique to use, it requires little training and has been shown to give reproducible results.

By means of the power function $S=kC^n$, magnitude estimation provides a method of predicting sensory response (S) from a known physical response (C) to an attribute. The value k is a constant and n is the exponent which measures the growth of sensory response with increases in the physical response. The power function can be transformed by logarithims to the equation $\log S = \log k + n \log C$. From this equation, n becomes the slope of the regression line relating log S to log C and log k becomes the y intercept (Stevens, 1960).

When n is greater than 1.0, the perceived sensory intensity grows more quickly than the physical intensity. If however, n is less than 1.0, the physical intensity grows more quickly than the perceived intensity. When n equals 1.0, the relationship is linear and both ratios are said to grow at the same rate.