A COMPARISON OF THE EMULSIFICATION CAPACITIES OF SOME PROTEIN CONCENTRATES

INTRODUCTION
THE FUNCTIONAL properties of protein isolates is a primary factor determining their utility in food products. Solubility, whipping ability, emulsification capacity and similar properties are used in determining potential food systems in which a given isolate may lend its desirable properties.

The emulsification capacity of proteins is of utmost importance to their utilization in salad dressings and comminuted meat products (Borton et al., 1968). The action of proteins as emulsifiers is influenced by protein concentration, speed of mixing, type of oil, and type of emulsification system.

The methods of detecting emulsion inversion have been subject to a lack of precision. Several methods for the determination of the endpoint, or collapse of emulsions, have been employed. Swift et al. (1961), Carpenter and Saffle (1964), Pearson et al. (1965), Borton et al. (1968) and Ivey et al. (1970) visually observed the abrupt decrease in viscosity associated with emulsion inversion. Goulden (1961) employed infra-red absorption to analyze the natural emulsion in milk, but was limited to discontinuous phase particles of uniform and limited size. Electrical conductivity was used by Webb et al. (1970), to determine emulsion endpoints but was effective only in dilute protein solutions. Acton and Saffle (1972) determined that a phase volume factor exerted some control over the maximum level of oil incorporation into emulsions using meat proteins as the emulsifier.

This investigation was undertaken to compare the emulsification capacities of four proteins under standardized conditions using a more sensitive and objective method than previously used for endpoint determination.

EXPERIMENTAL

Materials
The emulsification capacity of four protein preparations was compared over a range of protein concentrations. The two plant proteins studied were a glandless cottonseed flour (57.5% protein) and a soybean concentrate (67.5% protein). The two proteins of animal origin used were a decolorized bovine hemoglobin (Tybor et al., 1973) (90.1% protein) and a low heat nonfat dry milk (35.4% protein).

Protein determinations were made by the Kjeldahl procedure (AOAC, 1970). The protein preparations were suspended in distilled deionized water to produce a stock suspension containing 10 g protein per liter. Dilutions of this suspension were made by transferring the required volumes to 100 ml flasks and bringing to volume. The entire 100 ml volume was used in the determination of emulsification capacity. Corn oil was chosen arbitrarily as the oil phase for this study.

Methodology
Emulsions were formed in a Waring Blender equipped with a water-jacketed stainless steel cup. The Blender was operated in series with a variable autotransformer and a micro ammeter which could be attenuated for sensitive measurement of peak amperage requirements. The diagram of the attenuation circuit is presented in Figure 1.

The 100 ml aliquots of protein suspension were mixed in the Blender for 1 min at a transformer setting of 30 to thoroughly disperse the proteins. The transformer then was set at the desired speed and oil added until emulsion collapse occurred. The increasing viscosity during emulsion formation caused a steady rise in amperage requirements of the Blender motor. The sudden drop in viscosity at inversion resulted in a sharp drop in amperage, allowing a precise determination of the inversion point. The volume of oil required to reach the inversion point was expressed as a percentage of the total emulsion volume (volume of protein solution plus oil added) and this figure used for comparing the emulsification capacity of the proteins studied. This method has recently been reported by Acton and Saffle (1972) as an effective one for comparison of emulsification capacity.

Protein solubility measurements were made by a modification of the method of Lawhon and Cater (1971) utilizing the Lowry et al. (1951) method for determining soluble protein.

RESULTS & DISCUSSION
THE FIRST STEP in the study was to optimize the effects of blender speed, oil addition rate and pH on emulsification capacity of the proteins. Since proteins of different origins were to be compared, meaningful interpretation required optimization for each individual protein in terms of factors affecting its emulsification capacity.

Blender speed
The effect of Blender speed on the emulsification capacity of the proteins
was determined at autotransformer settings from 40 to 100. The results are presented in Table 1. Increasing Blendor speed decreased the oil phase volume at inversion for all samples, confirming the results of Ivey et al. (1970) and Swift et al. (1961). Insufficient mixing usually was observed at transformer settings below 80, resulting in erroneously high oil phase volume percentages. This effect is evidenced at the 40 setting for soy protein, and is responsible for the other missing data which were arbitrarily excluded. The effect was noted particularly for the globin fraction, and was least important for the soy protein for which settings as low as 50 could be used with satisfactory incorporation of the fat. The maximum oil phase volume for the milk proteins was attained at a setting of 60. However, most complete and rapid incorporation of fat was accomplished at a setting of 70. The optimum autotransformer settings were determined to be 80 for the soy, cottonseed and globin proteins, and 70 for the milk proteins. The use of these optimum blending speeds may not allow exact comparison with results obtained under conditions of constant blending speeds particularly when rate of oil addition is optimized.

**Rate of oil addition**

The effect of the rate of oil addition was determined by adjusting the addition rates between 0.40 ml/sec and 2.00 ml/sec. Figure 2 summarizes the results of different oil addition rates.

The oil addition rates did not appreciably affect the emulsification capacity of the soy, globin and cottonseed proteins. A rate of 0.67 ml/sec was determined to be optimum with respect to accuracy of oil volume determination at inversion and the time required for total oil addition. The optimum rate for the milk proteins was 1.00 ml/sec after which a sharp decrease in emulsification capacity was noted. Carpenter and Saffle (1964) concluded that varying the rate of oil addition had no effect although Swift et al. (1961) indicated a positive linear response. It was concluded from these findings that the rate of oil addition has an effect on certain proteins while others are unaffected.

**pH effect**

The effect of pH on emulsification capacity was determined over the range of pH 3 to 10. The results presented in Figure 3 indicate that at low pH values, a relatively high emulsification capacity was obtained for all but the cottonseed protein. With increasing pH, a decrease to a minimum point was noted followed by an increase in emulsifying capacity. The resulting curves resemble typical protein solubility curves, Swift and Sulzbacher (1963) likewise demonstrated that emulsification capacity correlated with the pH of the protein suspension.

**Protein solubility**

The solubility of the proteins over a range of pH values was determined to relate protein solubility to emulsification capacity. Solubility as a function of pH was determined over the range of pH 3 to 10 using the Lawhon and Cater (1970) method. The results are presented in Figure 4. Solubility of the proteins was highest at low pH values and decreased to a minimum after which solubility once again increased. A general correlation between emulsification capacity and solubility was evident, particularly between the minimum points for emulsification capacity (Fig. 3) and solubility (Fig. 4).

Pearson et al. (1965) observed similar results between emulsifying capacity and protein solubility. Based on these solubility data, the optimum pH values to be used for emulsification capacity comparisons of the protein samples were 9.4 for the soy protein, 3.1 for the globin, 8.9 for the cottonseed, and pH 7.1 for the milk proteins. These pH values were chosen to maintain a high level of protein solubility.

In instances of emulsion formation without regard to pH, protein solubility might not be optimized. Figure 5 shows the oil phase volumes of soy proteins and cottonseed protein at pH 9.4 and 8.9 respectively for optimum protein solubility and also near neutrality (pH 7.3 and 6.5 respectively). When protein solubility is optimized, a lower protein concentration is required to obtain the oil phase volumes similar to those at neutrality.

**Protein concentration**

Becher (1965) indicated that the emulsification capacity of several emulsifiers is related to the emulsifier concentration. Such a relationship for the proteins under study would indicate valid comparison only at the optimum concentration for each. Emulsification capacities were determined for protein concentrations between 0.200g/100 ml and 1.70g/100 ml of aqueous phase. The results are presented in Figure 5. Increase in concentration resulted in increased emulsification, corroborating the data of Carpenter and Saffle (1964) from extracted meat proteins and Webb et al. (1970) from sea bass extracts.

![Fig. 2 Effect of oil addition rate on percent oil phase volume of emulsion at inversion.](image-url)
The optimum concentration was largely dependent upon the protein type. The soy protein attained optimum emulsifying capacity at a concentration of 0.986g/100 ml. The globin attained optimum emulsifying capacity at 0.404g/100 ml. A globin concentration greater than 0.451 resulted in inadequate mixing due to the emulsion viscosity. Cottonseed protein concentration was optimum at 0.884g/100 ml, while the concentration of milk proteins was optimum at 1.19g/100 ml.

Valid comparisons of the emulsification capacities of the proteins could be made when the Blender speed, protein concentration, rate of oil addition and pH for maximum protein peptization were optimized for each protein sample. Of the four proteins studied, the bovine globin exhibited the greatest emulsification capacity, inverting at an oil phase volume of 83.9% at a concentration of 0.40g protein/100 ml. The soybean concentrate attained an optimum emulsification capacity (28.7% oil phase volume at a concentration of 0.986g/100 ml. The maximum oil phase volume of 75.8% for the cottonseed protein required a concentration of 0.884g/100 ml. The milk proteins gave an optimum response of 75.5% oil phase volume at a concentration of 1.19g/100 ml. This emulsion also exhibited a lower viscosity at inversion than the globin emulsion.

The globin produced the best emulsion of the four protein preparations studied when they were compared on a unit protein basis. However, it must be noted, particularly for the soy and cottonseed proteins, that several methods of isolation are possible and the functional properties may vary with the method of isolation.

REFERENCES


Ms received 7/2/73; revised 9/7/73; accepted 9/11/73.

Technical Paper No. 10600 of the Texas Agricultural Experiment Station, College Station, Texas. This research was supported by a grant from the Fats & Proteins Research Foundation, Inc., Des Plaines, Ill.