THE EFFECTS OF MICROWAVE HEATING ON THE PROPERTIES OF RAW UNEXTRACTED SOYBEANS FOR UTILIZATION BY THE CHICK

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ABSTRACT

THE EFFECTS OF MICROWAVE HEATING ON THE PROPERTIES OF RAW UNEXTRACTED SOYBEANS FOR UTILIZATION BY THE CHICK

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Soybeans contain, in addition to the high quality protein present, an excellent energy source for the chick, in the form of soybean oil. For unextracted soybeans to be efficiently utilized by the chick, they must be heated. This study was conducted to evaluate microwave heating as a means of producing an unextracted soybean product which may be satisfactorily utilized by the chick.

Samples of soybeans that had been subjected to microwave heating were analyzed for urease activity and protein dispersibility to establish the most effective treatments. Soybeans which had been effectively heated, as indicated by the analyses, were ground and included in an experimental chick diet for a biological analysis. Observations were made on weight gains, feed consumption, and pancreas weights.

Heating soybeans with microwave energy effectively destroyed the factor(s) responsible for pancreas enlargement. Also, the feed efficiency levels of chicks fed microwave heated soybeans nearly equaled those of chicks fed the diets containing soybean meal supplemented with either soybean oil or animal fat. However, the weight gain of chicks fed the diet containing microwave heated soybeans was less than that of chicks fed either of the diets containing soybean meal.

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INTRODUCTION

The soybean, *Glycine max*, is native to Eastern Asia. Early writings indicate that the soybean was perhaps one of the oldest crops cultivated by man and also was regarded as having many medicinal values.

Early in the Nineteenth century, soybeans were first brought to America and grown primarily as a forage and pasture crop. More than a century elapsed before they were produced commercially for processing purposes.

Commercial soybean meal is the major protein product utilized for livestock and poultry feeds in the United States. More than half of the soybean meal is consumed by the poultry industry via its high protein feeds. The protein quality or amino acid balance of soybean meal probably excels that of any other plant protein product available for use in animal feeds. In the commercial processing of soybeans, moisture, pressure, heat and solvents are involved in the oil removal process. The 44- and 49% protein, heated meals remaining after oil removal are the materials which are incorporated into animal feeds.

In the past, the price of soybean meal has been highly correlated with the price obtained for soybean oil as a human food. In recent years, there has been a greater need for soybean meal and a reduced demand for soybean oil. If this trend prevails, the price of the oil may be lowered to the extent that it will not be economical to process soybeans for oil removal.

High energy livestock and poultry feeds have been widely accepted due to the resultant improved growth performance. Fats and tallows are frequently incorporated into these feeds as supplemental energy sources. The occasional low soybean oil prices together with the acceptance of high energy feeds has created an interest in feeding unextracted soybeans with their characteristic high oil content.

Raw soybeans are poorly utilized by monogastric animals, therefore, they are subjected to various heat treatments. Microwave radiation is a revolutionary process in which heating is accomplished by direct absorption of energy. As the microwaves penetrate, they produce instantaneous heat, not only on the surface, but deep inside the material as well. The molecules are rapidly set in motion. Thus, heat is generated quickly and uniformly, thereby maximizing heat efficiencies. Toasting the intact soybeans with microwave radiation should produce a highly uniform product, eliminate the cost of fat extraction, and accelerate processing. The development of a method to process raw whole soybeans by microwave radiation would be of scientific interest and economic importance. The purpose of this research was to determine if microwave processing was effective in producing a heated soybean which would perform well in chick diets.

REVIEW OF LITERATURE

The growth arresting effect experienced when raw soybeans are fed to monogastric animals was initially reported many years ago. In studies with rats, Osborne and Mendel (1917) reported an increase in the rate of growth when the soybean portion of the ration had been heated in comparison with a raw soybean ration. These same investigators demonstrated the superiority of moist heat over dry heat. Numerous investigations with unheated and heated soybeans have since been conducted. These inquiries have confirmed the beneficial effect of moist heat on the nutritive value of soybeans and soybean meal for chickens, rats, and other monogastrics (Hayward, Steenbock and Bohstedt, 1936; Parsons and Walliker, 1941; Evans and St. John, 1945; Borchers, *et al*., 1947; Fritz, Kramke and Reed, 1947; McGinnis and Evans, 1947 and Rackis, 1966).

The unextracted soybean recently has been the subject of considerable interest and research as a poultry feed ingredient. In about 1959, this research was stimulated when soybean oil prices were low enough in relation to those of other feed fats to allow serious consideration of the oil for animal feeding. With a metabolizable energy of over 8,800 calories per kilogram, soybean oil is an excellent energy source for the young chick. It is logical to use the bean itself as a source of both protein and oil in poultry feeds rather than going to the trouble of extracting the oil from the bean and recombining it with soybean meal (Nesheim, 1961).

Presupposing the development of a satisfactory commercial process for producing cooked-unextracted soybean meal, several agricultural economists (Poats, Doty and Eley, 1961) conducted economic feasibility studies on the incorporation of this feed ingredient into poultry feeds. The analysis was made at a time when, due to the price of soybeans and soybean oil, the potential return from using soybeans as unextracted meal was attractive. These economists indicated the following advantages which would accrue to the feed mixer upon utilization of cooked-unextracted soybean meal which are not directly related to ingredient prices:

1. The addition of fats to feeds is a problem. Availability of a granular high-fat-content ingredient (such as cooked soybeans) would circumvent the large capital requirements necessary for and costs associated with making high energy feeds.
2. Unextracted soybean meal manufactured under quality controlled conditions would be a consistently high quality energy source. The caloric value of soybean oil exceeds that of feed grade fats and is more constant in nature.
3. Having the fat within the matrix of the feed particle rather than sprayed on its surface would permit higher energy content feeds to be made.

This initial feasibility study was revised and expanded upon by Doty (1965).

Numerous workers have reported on various means of heating unextracted soybeans for chick rations. The methods investigated to date include steam heating at various pressures, extruding and infrared heating.

It was concluded by Carew, Renner and Hill (1959) that autoclaved, flaked soybeans were at least as efficient as commercial soybean meal and degummed soybean oil for stimulating chick growth and improving feed conversion efficiency. A report by Renner and Hill (1960) indicated that autoclaved, ground soybeans were equally as effective in promoting rapid growth as the combination of autoclaved, extracted soybean flakes and soybean oil, despite the lower absorbability of the oil supplied by the unextracted soybeans.

The results of an experiment by Carew, Hill and Nesheim (1961) demonstrated that autoclaved, dehulled, unextracted soybean flakes produced a growth rate and feed efficiency equal to that obtained with the combination of soybean meal and degummed soybean oil while autoclaved, ground, unextracted soybeans were less satisfactory in this respect. The poorer results obtained with autoclaved, ground, unextracted soybeans was shown to be related to a reduced absorbability of the oil contained in them.

Yates (1963) reported that autoclaved (248° F. for 15 minutes), ground soybeans supported significantly lower gains than did soybean meal with added corn oil when fed to chicks from age two weeks to age six weeks.

Stephenson and Tollett (1959) utilized two forms of steam heating in producing heated soybean flakes. The flakes were processed in a rendering plant cooker or in a laboratory autoclave. The steam-cooked soybean flakes produced gains which were comparable to those produced with soybean meal and animal fat.

Combs (1960) reported on two feeding trials with broilers grown under commercial-like conditions. The broilers receiving a diet containing ground whole soybeans, processed at atmospheric pressure in a meat scrap cooker, weighed only slightly less than the controls at 12 weeks of age. In a second test, soybeans were processed at both atmospheric pressure and at 15 pounds of steam pressure for various lengths of time. Again, the controls receiving solvent extracted commercial soybean meal and feed grade fat performed slightly better than the broilers on any of the other treatments.

Continuous processing of whole soybeans was carried out in a regular solvent extraction soybean plant by Runnels (1961). The soybeans passed through the normal plant cycle, with the exception of being diverted around the extractors, and the resultant flakes were cooked similar to the method by which commercial soybean meal is processed. Also, ground and flaked soybeans were batch processed in a meat scrap cooker. The results of feeding trials with broilers approached those obtained with commercial meals.

Utilizing a steam-jacketed cylinder, Rogler and Carrick (1961) heated whole soybeans with additional injected steam and ground soybeans without supplementary injected steam. Feeding trials yielded growth results for both experimental rations which exceeded the growth rate supported by a soybean meal ration, but less than that of a soybean meal ration with added soybean oil. The feed efficiency levels derived from the high energy rations were nearly equivalent.

It was demonstrated by Mustakas _et al_. (1964) that the rate of gain and efficiency of feed conversion for extruded full-fat soybeans equaled that of soybean meal with added oil when fed to broiler chicks. Supplementation studies suggest that the methionine and cystine in the extruded product were probably more available which could account for the higher biological values obtained for chick feeding. The high nutritive value of the extruded soybean material was attributed to the relatively high temperature -- short retention time process. Growth inhibitors were effectively destroyed; whereas, the heat-labile amino acids, vitamins and other nutrients were preserved.

Featherston and Rogler (1966) employed autoclaving and infrared radiation as a means of heating unextracted soybeans for maximum utilization by the chick. When chicks were fed cracked, autoclaved soybeans the weight gain and feed efficiency achieved were statistically equivalent to that obtained with a corn-soybean oil meal ration with an equivalent amount of soybean oil added. The substitution of ground, infrared heated soybeans for soybean meal, soybean oil and a portion of the corn in the positive control diet on an isonitrogenous and isocaloric basis resulted in significantly poorer growth and feed conversion. Pancreas size of the chicks fed diets containing raw soybeans was markedly enlarged. The pancreases of chicks fed the infrared heated soybeans were much smaller than those of chicks fed the raw soybean diet but were larger than those of chicks fed the corn-soybean meal-soybean oil diets. No improvement in growth performance was observed when the moisture content of the soybeans was increased by 10% prior to infrared heating, in comparison with infrared heating dry soybeans. However, similar pancreas weights were observed in chicks fed diets which contained soybeans which had been moisturized prior to infrared heating as was observed in chicks fed the control diets containing commercial soybean meal.

White et al. (1967) evaluated the processing methods of autoclaving, extruding and infrared cooking for the production of cooked, unextracted soybeans for broiler rations. The results of this study indicate that autoclaving, extruding and infrared cooking significantly improved the feeding value of raw-unextracted soybeans to the extent that this material may replace soybean meal in broiler rations. Soybeans processed by these three methods approached the nutritional value of extracted soybean meal and soybean oil in isocaloric-isonitrogenous rations when fed to broiler chicks from 7 to 28 days of age.

Experiments were also conducted by Hull et al. (1968) to evaluate infrared cooking and extrusion processing of unextracted soybeans for inclusion in broiler diets. It was reported that diets containing extruded soybeans supported chick performance equal or superior to feeds containing solvent extracted soybean meal with soybean oil added; whereas, infrared cooked beans were usually inferior to solvent extracted soybean meal with added soybean oil.

Rackis (1968) recommended the use of urease activity and protein dispersibility tests as guides to indicate properly processed soybean meal. He suggested that if the urease activity indicated a pH increase from 0.05 to 0.15 and if the protein dispersibility index (PDI) was from 10 to 20%, the soybeans were considered to have been properly processed.

MATERIALS AND METHODS

Soybean Treatments and Analyses

At the outset of this experiment, three variables existed -- batch size heated, moisture content of the beans and heating period. The first variable to be standardized was the batch size heated. To accommodate the size of the oven[1] and for convenience, a batch size of 1,800 grams was selected.

From every trial batch heated, a minimum of one sample of approximately fifty grams was removed for an analysis of optimal heating. If the sample was too moist to grind, it was dried overnight at 40° C. in a drying oven. Each sample was ground through a Number-10 Wiley mill screen and extracted with redistilled n-hexane in a Soxhlet extractor. The resulting meal was then desolventized overnight at 40° C. The urease activity and the protein dispersibility index (PDI) of each sample was determined following procedures outlined by the American Oil Chemists' Society (1965). The guidelines provided by Rackis (1968) were then applied to determine the effectiveness of the heating procedure.

In a pre-experiment trial, raw dry (5.9% moisture) soybeans were heated in the microwave oven. The soybeans were cooled at room temperature, but were not further dried, prior to grinding, due to

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[1]Hotpoint Model 20 RER 1 powered by one magnetron (Raytheon QK 390) providing a frequency of 2,450 megahertz (MHz) and an output of 0.8 kilowatts.

their low moisture content. Urease analysis was then conducted on several samples as outlined.

The next trial was designed to assess the effects of heating beans of different moisture contents. Two identical batches of beans were soaked in water for 5 or 15 minutes, respectively. After soaking, the beans were held overnight under refrigeration in sealed containers to allow uniform moisture distribution (Renner and Hill, 1960). Individually, 1,800 grams of each moisturized batch were placed in the oven. After six minutes of heating, and every two minutes thereafter, the beans were removed from the oven, stirred, sampled, and returned to the oven, until a total heating time of twenty minutes had elapsed. Each sample was cooled at room temperature, dried overnight at 40° C., ground, extracted, desolventized and analyzed as previously mentioned.

In the previous trial, in which the desirable moisture level was ascertained, the batch size decreased with heating time as the samples were removed. Therefore, it was necessary in this trial to heat batches of soybeans undiminishing in size and nearly equal in moisture content to determine the most desirable heating interval.

Four batches of beans were soaked in water, each for five minutes, and refrigerated. The heating period ranged from 15 to 18 minutes. Each batch was stirred at two-minute intervals for the last ten minutes of the heating cycle. The heated beans were cooled to room temperature in shallow steel pans and a sample was removed from each batch. The heating process dried the beans considerably (to about 8% moisture), therefore, they were not further dried. Grinding, extraction, desolventizing and chemical analyses were performed as in the previous trials.

After having determined the correct relationships between batch size, moisture level and heating time, the next procedure was to heat several batches, employing this information, so that the chemical analyses might be substantiated by a chick growth trial.

Each of 13 batches was soaked in water for five minutes and refrigerated overnight. The soybeans were then heated for 15 minutes and each batch was stirred at two-minute intervals for the last ten minutes of the heating period. Each batch was poured into a shallow metal pan, cooled to room temperature and then sampled. The samples were of low moisture content, thus they were not further dried. Sample preparation and analysis was conducted as aforementioned.

Diet Formulation

In the growth trial phase of this experiment, all diets were formulated to be isonitrogenous and isocaloric. For the accuracy of the formulations to be increased, the feed ingredients which varied in amount among the diets were analyzed for protein, phosphorus and calcium. Energy values previously reported were utilized. Illustrated in Table 1 are the derived protein, phosphorus and calcium values and assumed energy values applied in formulating the diets.

The diets compared in this experiment contained soybean meal, microwave heated soybeans or raw soybeans. The soybean meal and soybean oil were commercial products; however, the microwave heated and the raw soybeans were both from the same lot (Harosoy-63 variety). The composition of the diets is given in Table 2. All diets were fed in the mash form. The microwave heated and raw soybeans were ground in a hammermill prior to inclusion in the diets.

Table 1. Protein, phosphorus, calcium and energy content of variable ingredients

Ingredient	Analyzed			Assumed
	Protein (%)	Phosphorus (%)	Calcium (%)	M.E. (Cal/lb)
Soybean meal	49.38	.707	.238	1,100[a]
Corn	8.88	.310	.010	1,560[a]
Microwave heated soybeans	39.25	.552	.151	1,500[b]
Raw soybeans	39.25	.552	.151	1,100[c]
Soybean oil	--	--	--	4,100[d]
Animal fat, stabilized (yellow grease)	--	--	--	3,480[a]

[a]Flegal and Adams, 1969.

[b]Waldroup _et al._, 1969.

[c]Hill and Renner, 1958.

[d]Young, 1963.

Table 2. Composition of diets

Ingredient	Diet number 1	2	3	4
Corn	57.74	56.07	54.07	46.83
Soybean meal	26.11	26.41	--	--
Microwave heated soybeans	--	--	33.68	--
Raw soybeans	--	--	--	35.52
Soybean oil	3.90	--	--	5.60
Animal fat, stabilized (yellow grease)	--	5.27	--	--
Constant ingredients[a]	12.25	12.25	12.25	12.25
Total	100.00	100.00	100.00	100.00
Calculated analysis:				
Protein (%)	21.00	21.00	21.00	21.00
Calcium (%)	.96	.96	.95	.95
Phosphorus, total (%)	.78	.78	.77	.76
Phosphorus, available (%)	.51	.51	.50	.50
Metab. energy (Kcal/kg)	3,172	3,174	3,174	3,174
Chemical analysis:				
Protein (%)	21.31	21.63	21.56	21.75
Calcium (%)	.91	.89	.97	.85
Phosphorus, total (%)	.79	.73	.76	.75

[a]Supplied 2.0% alfalfa meal (20% protein); 3% fish meal (60% protein); 2% corn distillers dried solubles (27% protein); 2% dried whey (12% protein); 0.5% salt; 1% ground limestone; 1.5% dicalcium phosphate and 0.25% vitamin-trace mineral mix (supplied the following in milligrams or units per kilogram: Vitamin A, 6,608 USP units; Vitamin D_3, 1,652 IC units; Vitamin E, 2.2 IU; riboflavin, 4.4 mgs; d-pantothenic acid, 6.1 mgs; niacin, 27.5 mgs; choline chloride, 275.3 mgs; menadione sodium bisulfite complex, 2.2 mgs; Vitamin B_{12}, .0088 mgs; BHT, 124.9 mgs; manganese, 60 mgs; zinc, 27.6 mgs; iron, 20 mgs; copper, 2 mgs; iodine, 1.2 mgs; cobalt, 0.2 mgs.)

Chick Growth Trial

One-day-old Cobb's strain White Rock broiler cockerels were placed in equalized weight groups, wing-banded, and three replications of ten birds each were randomly distributed in chick batteries.

The chicks were individually weighed at weekly intervals and feed consumption per lot was recorded. After having been on the test rations 28 days, the birds were sacrificed and their pancreases were excised and weighed.

Statistical Procedure

Significance of variations in growth, feed conversion and pancreas weight, as a percentage of body weight, were measured by analysis of variance (Snedecor, 1956) and Duncan's (1955) multiple range test. The 0.01 level of probability provides the basis for all statements concerning statistically significant differences.

RESULTS AND DISCUSSION

In the pre-experiment trial the urease analysis revealed that when dry (5.9% moisture) soybeans were heated with microwaves as outlined, the desired effects were not produced.

Soybeans which were soaked in water for five minutes attained a moisture content of 15.3% and those soaked for 15 minutes 20.8%. The results of the chemical analyses of meals derived from this second trial, in which soybeans of the two moisture levels were heated, is shown in Table 3 and Figures 1 and 2. In Figure 1, it can be seen that soybeans which contained 15.3% moisture prior to heating, required between 14 and 16 minutes of heating before both the urease and PDI levels were in their respective recommended ranges (Rackis, 1968). As can be seen in Figure 2, no such commonality of indices resulted for the 20.8% moisture soybeans. From these results, it was ascertained that approximately 15% moisture was desirable for heating.

The urease activity and protein dispersibility data derived from the third trial is presented in Table 4. In this trial, four batches of soybeans containing approximately 14.5% moisture were heated. The analysis of soybeans which had been heated for 15 minutes provided urease and PDI values which both approximated their recommended ranges, therefore, the desirable heating time under this set of conditions was considered to be 15 minutes.

Table 3. Urease activity and PDI values of soybeans containing different moisture levels and heated for various time periods

	15.3% moisture		20.8% moisture	
Heating time	Urease activity (pH change)	PDI (%)	Urease activity (pH change)	PDI (%)
Raw	2.080	86.0	2.080	92.7
12 minutes	1.145	45.4	--	--
14 "	0.145	29.8	0.465	39.6
16 "	0.015	16.0	0.030	26.0
18 "	0.015	12.1	0.010	15.4
20 "	0.005	10.0	0.005	12.1

Figure 1. Urease activity and PDI values of soybeans containing 15.3% moisture and heated for various time periods.

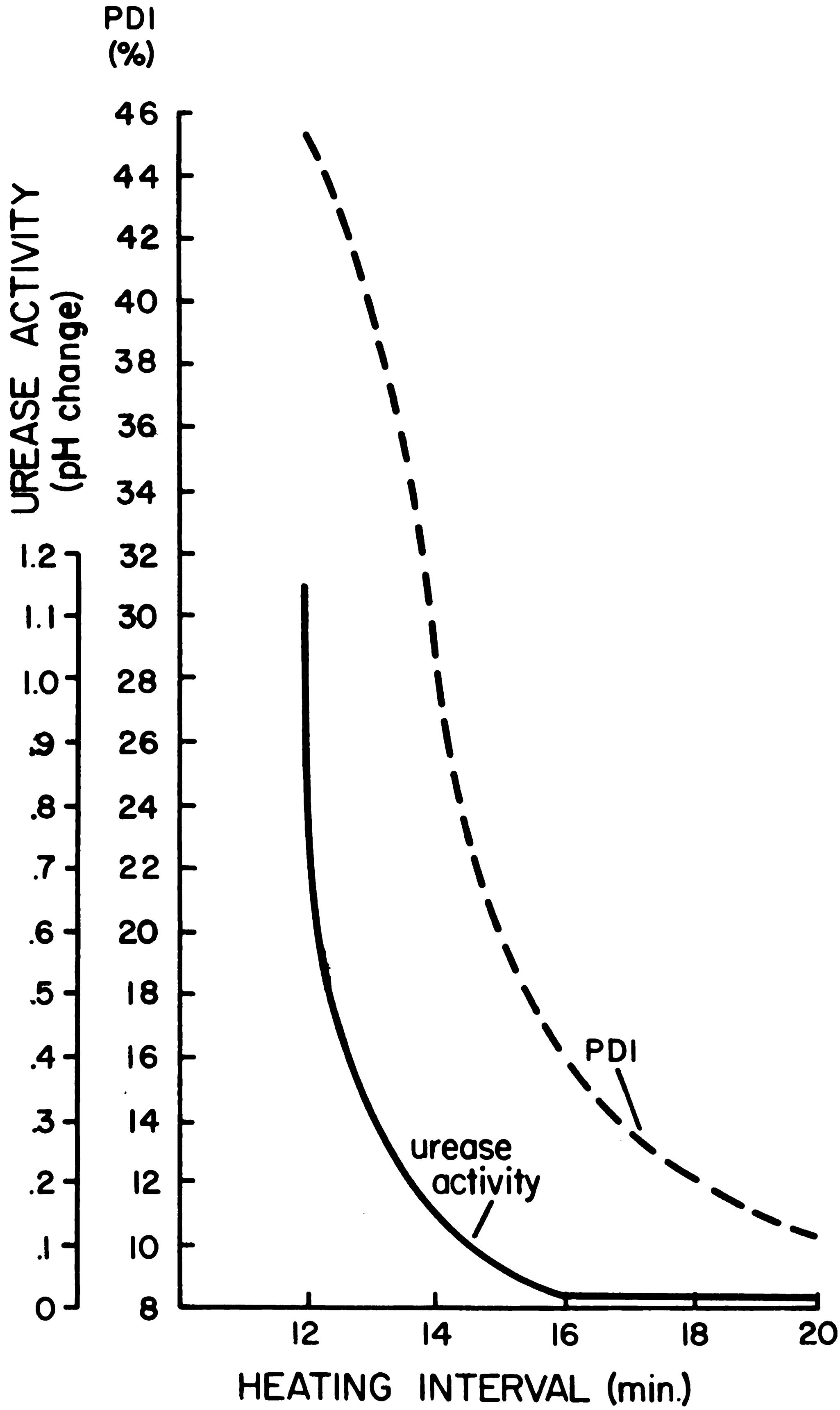
PDI
(%)
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
UREASE ACTIVITY
(pH change)
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
PDI
urease
activity
12
14
16
18
20
HEATING INTERVAL (min.)

Figure 2. Urease activity and PDI values of soybeans containing 20.8% moisture and heated for various time periods.

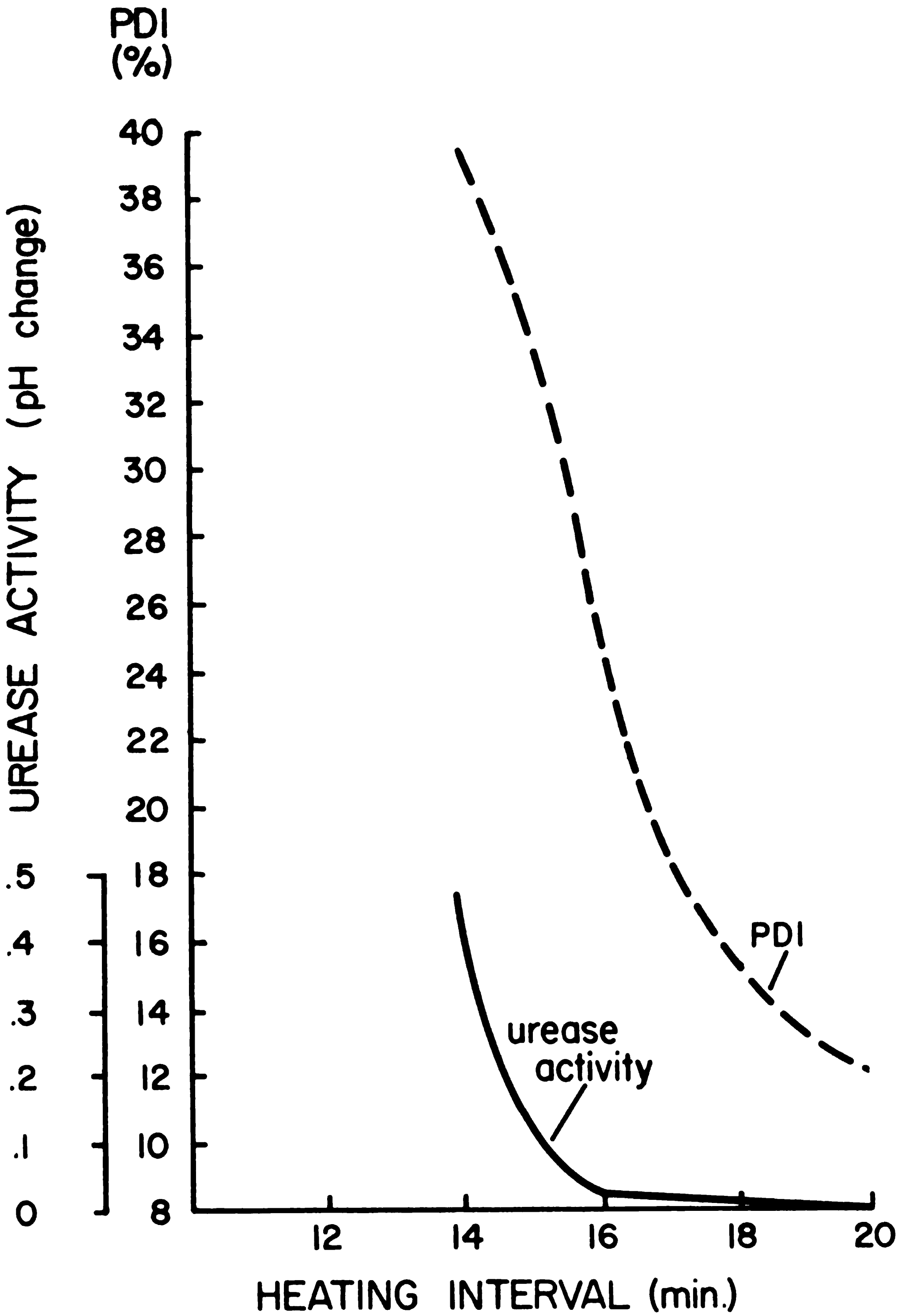
PDI
(%)
UREASE ACTIVITY (pH change)
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
.5
.4
.3
.2
.1
0
PDI
urease
activity
12
14
16
18
20
HEATING INTERVAL (min.)

Table 4. Urease activity and PDI values of soybeans containing an equal moisture level (14.5%) and heated for various time periods

Heating time	Urease activity (pH change)	PDI (%)
15 minutes	0.047	20.3
16 "	0.037	15.6
17 "	0.015	13.5
18 "	0.003	10.6

The data resulting from the chemical analysis of each of the 13 batches heated for the feeding trial and their moisture contents prior to heating can be seen in Table 5. As will be noted in the urease values for batches 1 and 6, there were some slight deviations from the suggested ranges, however, these were negligible. Thus, all 13 batches were considered acceptable for use in the chick growth trial and were combined together.

When the three soybean sources were compared in all-mash broiler diets, chicks fed the diets containing commercial soybean meal were significantly greater in body weight gained than chicks fed the diet containing microwave heated soybeans (Table 6). Chicks fed the diet containing raw soybeans grew significantly less than birds fed the diets containing commercial soybean meal or microwave heated soybeans.

Feed efficiency values did not vary significantly among those chicks receiving diets containing soybean meal or microwave heated soybeans (Table 6). Birds fed the diet containing raw soybeans were significantly less efficient in feed utilization than those chicks whose diets included soybean meal or microwave heated soybeans.

Chicks fed the diet containing raw soybeans manifested a marked enlargement of the pancreas when pancreas weight is expressed as a percentage of total body weight, hereafter referred to as pancreas weight (Table 6). Pancreas weights of chicks fed diets containing soybean meal or microwave heated soybeans were not significantly different.

The analyses of variance of chick weights, feed conversion and pancreas weights are provided in Tables 7, 8 and 9, respectively.

Table 5. Moisture content, urease activity and PDI values of soybeans heated and incorporated into chick diets

Batch number	Moisture (%)	Urease activity (pH change)	PDI (%)
1	15.1	0.028	15.5
2	13.7	0.054	17.0
3	15.1	0.078	18.5
4	13.1	0.050	15.7
5	14.7	0.046	16.3
6	14.0	0.030	16.1
7	15.4	0.058	17.4
8	15.4	0.085	20.2
9	16.0	0.050	18.8
10	16.6	0.103	20.6
11	15.5	0.095	18.8
12	15.2	0.080	19.8
13	16.0	0.109	19.1
Average	15.1	0.067	18.0

Table 6. Effect of different protein and supplemental energy sources on broiler performance and pancreas weight

Diet number	Protein-energy source	28-day body weight gain (gms)[a]	Feed/ gain[a]	Pancreas weight (% body wt.)[a]
1	Soybean meal-soybean oil	652.07 A	1.708 A	.257 A
2	Soybean meal-animal fat	647.54 A	1.661 A	.272 A
3	Microwave heated soybeans	575.23 B	1.850 A	.285 A
4	Raw soybeans-soybean oil	341.70 C	2.320 B	.602 B

[a]Means bearing the same superscript do not differ significantly $P < 0.01$; means not having the same superscript are significantly different ($P < 0.01$).

Table 7. Analysis of variance of four-week chick weights

Source of variation	Degree of freedom	Sum of squares	Mean square	F value
Total	142	2,510,762		
Subclass	14	1,864,951	133,211	26.405**
Treatments	4	1,818,661	454,665	90.122**
Replications	2	7,360	3,680	0.729
T X R (Int.)	8	38,930	4,866	0.965
Error	128	645,811	5,045	

Standard error of mean = 13.282

** Significant at the 0.01 level of probability

Table 8. Analysis of variance of feed conversion

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value
Total	14	1.023		
Treatment	4	0.837	0.20925	
T X R (Int.)	10	0.186	0.01860	11.250**

Standard error of mean = 0.0787

** Significant at the 0.01 level of probability

Table 9. Analysis of variance of chick pancreas weights

Source of variation	Degrees of freedom	Sum of squares	Mean square	F ratio
Total	142	2.876499		
Subclass	14	2.455433	0.175388	53.509**
Treatments	4	2.403426	0.600857	182.631**
Replications	2	0.010607	0.005304	1.612
T X R (Int.)	8	0.041400	0.005175	1.573
Error	128	0.421066	0.003290	

Standard error of mean = 0.01072

** Significant at the 0.01 level of probability

The results of this chick growth trial duplicate the results reported by Featherston and Rogler (1966). They compared chick diets containing ground infrared heated soybeans, which had been moisturized prior to heating, with diets containing soybean meal and soybean oil. The pancreas weight data of this trial also indicated that the factor(s) responsible for pancreatic enlargement had been destroyed by the infrared heating process. The chicks fed the unextracted heated soybeans did not grow as rapidly as the chicks fed the basal diet with added soybean oil. Feed utilization of chicks fed the diets containing the heated soybeans in some instances approached that of chicks fed the basal diet with added soybean oil. Their failure to obtain comparable growth in chicks fed unextracted infrared heated soybeans with that in chicks fed a corn-soybean meal diet with equivalent soybean oil added, and the results of published studies indicating a need for mechanical pressure in the processing of unextracted soybeans, led them to study the effects of pelleting and flaking in addition to the infrared heating of unextracted soybeans for chicks. The results of their study indicated that the heating of unextracted soybeans by infrared radiation when used in conjunction with some form of mechanical pressure resulted in an unextracted soybean meal which was well utilized by the chick. However, although the differences were not statistically significant, slightly better performance was obtained with a corn-soybean meal diet with an equivalent amount of oil added than could be obtained with the soybean product of any of the processing methods employed, which included pelleting, pelleting and regrinding, and flaking.

In addition, Hull et al. (1968) reported that when a diet containing infrared heated soybeans was pelleted and compared with the same diet in mash form, the pelleted diet resulted in significantly greater chick body weights. No significant body weight differences existed when the pelleted, infrared heated soybean diet was compared with a pelleted soybean meal-soybean oil diet. Pelleting did not significantly improve the feed efficiency of diets containing soybean meal-soybean oil over that of mash form, but it significantly improved the feed utilization of chicks fed diets containing infrared heated soybeans. The differences in feed efficiency which occurred when comparing pelleted soybean meal-soybean oil diets with pelleted infrared heated soybean diets were insignificant.

Carew et al. (1961) found that by compressing cracked soybeans into very thin flakes prior to autoclaving and including them in chick diets, the availability of the soybean oil in soybeans for chicks could be markedly improved, to the extent that the absorbability of the oil present in the soybeans closely approached that of soybean oil fed as such. Autoclaved, unextracted soybean flakes were found to be equally as effective as equivalent amounts of soybean meal and soybean oil in their ability to stimulate chick growth and improve the efficiency of feed utilization. In contrast to results with autoclaved, unextracted soybean flakes, autoclaved, ground unextracted soybeans were less effective. The poorer results obtained with autoclaved ground, unextracted soybeans were shown to be related to a poorer absorbability of the oil present in them. These investigators indicated that apparently the maximum value from autoclaved soybeans as a

poultry feed ingredient can be obtained only if a processing method is used that will allow maximum availability of the soybean oil present in them.

Numerous other investigators have reported that maximal chick growth or feed utilization has not been obtained as a result of the feeding of heated unextracted soybeans, and have experienced a marked improvement in chick performance as a result of the use of mechanical pressure in addition to heating in the processing of soybeans (Carew _et al._, 1959; Renner and Hill, 1960; Carew and Nesheim, 1962). The results of these preceding studies imply that mechanical pressure may supplement microwave heating of soybeans to improve the body weight gained and feed efficiency derived in comparison to that obtained from the feeding of ground microwave heated soybeans to chicks. It is possible that flaking the moisturized soybeans prior to subjecting them to microwave heating, rather than grinding the microwave heated beans, or pelleting the diet containing ground, microwave heated beans would increase the nutritional value of the soybeans to the chicks by causing a greater rupture of the cells with a concommitant increase in nutrient digestibility.

SUMMARY

This research was conducted to evaluate microwave heating as a method of processing unextracted soybeans for inclusion in broiler diets. The desirable soybean moisture content and heating interval were defined on the basis of chemical analyses. It was determined that microwave heating effectively reduced the urease activity and protein dispersibility of moisturized, unextracted soybeans to levels considered to be desirable for chick growth performance. A diet containing microwave heated soybeans was compared with soybean meal diets adjusted with soybean oil or animal fat to be isocaloric and a raw soybean diet made isocaloric with soybean oil. All diets were formulated to be isonitrogenous. The heated soybeans replaced all the soybean protein and the soybean oil or animal fat.

Chicks fed the microwave heated soybeans performed, in reference to feed conversion and pancreas weight, equally as well as chicks fed the control soybean meal diets and better than chicks fed the raw soybean diet. However, chicks fed the microwave heated soybeans did not grow as rapidly as the chicks fed either of the soybean meal control diets, but grew more rapidly than chicks fed the raw soybean diet.

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