Rapid Improvement in Nutritional Quality of Soybeans by Dielectric Heating

**INTRODUCTION**

Heat treatment of soybeans to inactivate intrinsic growth inhibitors has been limited to a temperature times pressure times moisture interaction (Osborne and Mendel, 1917; Hayward et al., 1936). Presumably, the pressure effect increases the possible temperature while moisture is necessary to mediate some as yet unidentified biochemical reaction accomplishing inactivation of the growth inhibitor. Dry oven heating was noted by Osborne and Mendel (1917) to be quite ineffective in improving the nutritive value of soybeans; an observation supported by recent unpublished data in our laboratory, even after increasing the initial moisture content of the beans to 30%.

In conjunction with studies of radiofrequency (RF) dielectric heating on a variety of agricultural and related products, we have investigated the effect of this type of energy on the nutritive value of soybeans. A rapid inactivation of the growth inhibition effect in whole dry soybeans was observed yielding a product with little browning.

**MATERIALS & METHODS**

Soybeans of the Wayne variety were purchased from a local producer shortly after harvest in the fall of 1969. At the time of use in these studies the beans contained: 8.4% moisture, 36.3% protein and 18.4% fat.

Radiofrequency dielectric heating

The whole soybeans were processed in a modified General Electric model 4HD3B2 electronic dielectric heater described by Nelson and Whitney (1966) with further modifications (Nelson et al., 1966). The unit operated at a frequency of 43 megahertz with no modulation.

Approximately 180g quantities of soybeans were treated in completely filled Pyrex petri dishes, nominally 15 cm in diam x 2 cm deep, between parallel plate electrodes spaced 3.4 cm apart, leaving an air gap of 1.4 cm above the petri dish. The average intensity of the electric field in the soybeans was 0.65 kV/cm, calculated from the measured RF electrode voltage and dimensions and relative permittivities of the materials using the following relationship: 

\[ E = \frac{V}{\sqrt{d_1 + \frac{d_2 (e_1/e_3) + d_3 (e_2/e_3)}}} \]

where \( V \) is the rms RF electrode voltage; \( d \) the thickness of each material measured perpendicular to the plane of the electrodes; \( e \) the relative permittivity; and subscripts 1, 2 and 3 denote the material: soybeans, Pyrex glass and air, respectively.

Estimates of soybean temperature were obtained by probing samples with glass braid insulated No. 30 gage copper-constantan thermocouples immediately after exposure to the RF field through a hole provided in the side of the petri dishes. Temperature measurements were made with a Leeds & Northrup Type 8663 indicating potentiometer. Temperatures listed are averages of the maximum readings obtained on each of four samples treated at each exposure. Samples were permitted to cool in the petri dishes.

After processing, the soybeans were milled and defatted with diethyl ether prior to determination of browning, protein solubility, urease and trypsin inhibitor. The material was not defatted for feeding tests with rats.

Color browning index

The defatted soybean meal was extracted with 10 vol distilled water overnight at 4°C. Water soluble nitrogen was determined by the conventional Kjeldahl procedure and expressed as percent of the total nitrogen.

Urease activity

Urease activity was determined essentially by the method of Summer (1955). Increase in ammonia nitrogen was measured by the Nessler reaction. Urease activity was expressed as the \( \mu \) moles of ammonia liberated per minute per g of defatted meal.

Trypsin inhibitor activity

Trypsin was assayed by the casein digestion method of Kunitz (1947) and Lackowski (1955). One trypsin unit was defined as that activity which liberated 1 \( \mu \) mole of tyrosine color equivalent per minute from 1% casein at pH 7.6 and 37°C. One trypsin inhibitor unit was that activity which decreased the trypsin activity by 1 unit and is expressed as units per g of defatted meal.

**RESULTS & DISCUSSION**

**Table 1—Effect of radiofrequency dielectric heating on soybeans**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Browning</th>
<th>Protein solubility</th>
<th>Urease</th>
<th>Trypsin inhibitor</th>
<th>Rat growtha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C</td>
<td>A</td>
<td>%</td>
<td>units/g</td>
<td>g/day gain (g food)</td>
</tr>
<tr>
<td>None</td>
<td>0.22</td>
<td>55</td>
<td>737</td>
<td>193</td>
<td>1.09 ± 0.11a</td>
</tr>
<tr>
<td>RF dielectric heating</td>
<td>0.83</td>
<td>127</td>
<td>0.21</td>
<td>13</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>132</td>
<td>0.25</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>1.67</td>
<td>146</td>
<td>0.29</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>168</td>
<td>0.33</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Steam autoclaving</td>
<td>0.83</td>
<td>120</td>
<td>0.49</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>120</td>
<td>0.49</td>
<td>14</td>
<td>9</td>
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<tr>
<td></td>
<td>1.67</td>
<td>120</td>
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<td>120</td>
<td>0.49</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

aFor details of treatment and measurements, see Materials & Methods section of the text.

bValues with different superscripts are significantly different, \( P < 0.01 \).
meal as a food or feed, it must be thoroughly cooked so maximum nutritive value will be expressed. The usual method of cooking or roasting requires steam autoclaving at 15 psi for 20–30 min (Borchers et al., 1948). Heat treatment of raw, whole soybeans in the dielectric heater effected maximum improvement of the nutritive value of the soybeans in less than 2 min. Temperature attained by the soybeans in this time was 146°C. The results are presented in Table 1. As is true with steam autoclaving of soybeans, optimum heat treatment is attained under specific conditions; under- or over-heating resulted in a product of lesser nutritive value. The important advantage of dielectric heating arises from the effectiveness of the method with air dried, whole beans; addition of moisture was not necessary.

Other parameters of the soybeans noted to change when soybeans are steam autoclaved were noted with the dielectric cooking. The water solubility of the soybean protein decreased as did urease and trypsin inhibitor activities. Browning also developed but at a slower rate than observed when soybeans are steam autoclaved.

Extension of the RF dielectric cooking of soybeans from a laboratory to a commercial scale is difficult to evaluate at this time. Possible commercial advantages of the process would need to be carefully assessed in relation to the investment and operating costs for such an installation.

REFERENCES


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Mention of specific equipment is made for purposes of identification and does not imply endorsement by the USDA or the University of Nebraska.