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Effects of roasting and electron beam irradiating on protein characteristics, ruminal degradability and intestinal digestibility of soybean and the performance of dairy cows

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ABSTRACT

Various methods of processing soybeans (SB) may help to decrease its extent of ruminal degradation, thereby providing more nutrients needed for high producing dairy cows. Two experiments (*in situ* and *in vivo*) were conducted to examine the effect of roasting and electron beam irradiating on ruminal degradability and intestinal digestibility of SB and performance of dairy cows. In the *in situ* trial, nylon bags of untreated (USB), roasted (RSB), and irradiated (ESB) soybean were incubated in the rumen of three non-lactating cows for up to 48 h. Additional samples of each SB product were also incubated for 12 h in the rumen; the residues from these bags were transferred to mobile bags, soaked in pepsin HCl, and then used for determination of intestinal digestibility. The results showed that the roasting processing was an effective method of changing the site of digestion from the rumen to the small intestine and therefore the amount of digestible crude protein (CP) in the small intestine can be increased. However, total tract disappearance of CP was not significantly different between USM and RSB. Irradiation of SB increased ($P<0.05$) protein solubility and the degradation rate of the potentially degradable fraction of protein, and decreased ($P<0.05$) the slowly degraded true protein (B_3 fraction) compared to USB. Intestinal digestibility and total tract disappearance of CP were also lower ($P<0.05$) for ESB than USB and RSB. Proteins of untreated and treated SB residues were fractionated by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). Based upon electrophoretic patterns, the basic subunits of glycinin formed the major component of escaping protein in ESB while those in RSB samples were the subunits of glycinin and β-subunits of conglycinin. In the *in vivo* trial, nine lactating Holstein cows (610 ± 23 kg and 141 ± 4 d in milk) were used in a 3×3 Latin square design with 21-d experimental periods. Treatments had no effect on ruminal ammonia concentrations and blood urea nitrogen. Dry matter intake tended ($P=0.11$) to be lower in cows fed RSB diet compared to those fed USB and ESB diets. Roasting improved the efficiency

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milk yield of the lactating cows while irradiation had no impacts on milk production. In conclusion, roasting improved the efficiency of SB protein utilization and milk yield, whereas irradiation increased the rate of ruminal degradation of CP and had no effect on lactation performance of dairy cow.

1. Introduction

In ruminant, the major contribution to duodenal protein flow is microbial protein with high biological value. However, the high-producing dairy cow requires a significant amount of rumen escape protein (Boisen et al., 2000). Full-fat soybean (SB) is used as a source of protein (containing essential amino acids) and energy in the ration of high-producing dairy cows (Chouinard et al., 1997); however, most of its protein content can be degraded by rumen microbes leading to a surplus ammonia production in the rumen (Froidmont et al., 2009). Many researches have been carried out to find ways to reduce ruminal protein degradation with variable degrees of success (Harstad and Prestløkken, 2000; Fathi Nasri et al., 2008; Shawrang et al., 2008). Several feed processing methods have been developed in order to decrease ruminal CP degradation such as extrusion, roasting, and gamma irradiation (Shawrang et al., 2007; Fathi Nasri et al., 2008; Taghinejad-Roudbaneh et al., 2010). Thermal processing is an industrial method for protecting SB protein from ruminal degradation (Chouinard et al., 1997). Heat processing has been reportedly capable of reducing the ruminal degradability of CP with a concomitant increase outflow and balance of amino acids to intestine (Petit et al., 1999). However, during thermal processing proteins may undergo chemical changes leading to a reduction of their nutritional value and biologically available amino acids. This may happen in the case of Maillard reactions which occur between reducing sugars and lysine in various products (Sarwar Gilani et al., 2012). Abdi et al. (2013) found that roasting of SB had no effect on milk production and composition, and apparent total tract digestibility of nutrients in lactating dairy cows. Irradiation is another set of processing technology that can be used in animal feed (Diehl, 2002), and it has high potential for substitution of other methods (Mani and Chandra, 2003). However, the technical difficulties and the cost of electron beam irradiation might prevent this process from reaching the marketplace. Gamma irradiation affects proteins by causing changes in proteins (*i.e.*, fragmentation, cross-linking, and aggregation), oxidation of amino acids, rupturing of covalent bonds and formation of protein free radicals (Lee et al., 2005). It has been reported that ruminal CP degradability of SB meal decreased linearly when it was irradiated with 25, 50 and 75 kGy of gamma ray (Shawrang et al., 2007). In 1997, an FAO/IAEA/WHO Study Group on High Dose Irradiation examined the results of safety studies carried out on food irradiated with doses higher than 10 kGy. Long-term animal feeding studies with foods irradiated with doses as high as 70 kGy have shown no treatment-related adverse health effects (WHO, 1999).

Not only is the available information concerning the effects of electron beam irradiation on ruminal and total tract digestibility limited, but there is also a lack of data on the performance of lactating dairy cows fed diets containing irradiated feed. Therefore, this study aimed at evaluating the effects of roasting and electron beam irradiation as two physical processing methods on ruminal degradability and intestinal digestibility of protein, and performance efficiency of lactating dairy cows.

2. Materials and methods

2.1. Roasting and irradiation treatments of soybean

In the current study, an Iranian cultivar of soybeans (cultivars, Williams-82) was used. Whole SB was roasted at 145 °C for 30 min in a hot air commercial roaster (Roaster Jet. Tehrandane Co., Tehran, Iran), and consequently, spread out on the ground for cooling. Soybeans samples of 7 kg were packed in polyethylene bags (40 × 70 cm with 2 cm thickness). The polyethylene package of sample was exposed to 60 kGy electron beam irradiation using Rhodotron accelerator (TT200, IBA Co., Louvain-la-Neuve, Belgium) in the Yazd irradiation center, Atomic Energy Organization of Iran. All irradiations were performed at room temperature. The samples were placed in a pallet and passed through the electron beam radiation field using a conveyor system for three cycles in the presence of air. At a setting of 10 MeV and a current flux of 2.0 mA, 1 passage resulted in an exposure of 21 kGy (63 kGy exit product). The dose rate was determined using cellulose triacetate films (ISO/ASTM 51650, 2005). Uncertainty for electron beam irradiation was around 3%. The dosage was chosen based on preliminary *in situ* studies of SB and canola meals irradiated at different doses (Shawrang et al., 2007, 2008) and the reported dose required for polymerization (Sarma, 2003).

2.2. Ruminal degradability, post-ruminal digestibility and determination of protein subunits

Three nonlactating, multiparous Holstein cows with average body weight of 620 ± 25 kg (mean ± SD) and fitted with ruminal and T-shaped duodenal cannulas were used for the *in situ* measurements of ruminal degradability and intestinal digestibility. The cows were housed in individual pens (1.8 × 2.9 m^2) and fed a total mixed ration (TMR) twice a day at 0800 and 1600 h in two equal portions. The cows were maintained on a standard diet consisting of 300 g/kg DM maize silage, 280 g/kg DM chopped lucerne hay, 210 g/kg DM wheat straw and 210 g/kg DM concentrate. The concentrate was composed of 358 g/kg DM wheat bran, 285 g/kg DM canola meal, 166 g/kg DM rice bran, 150 g/kg DM barley grain, 16.4 g/kg DM wheat, 15 g/kg DM mineral and vitamin mix, 6.6 g/kg DM calcium carbonate and 3 g/kg DM sodium chloride.