Enhancing the nutritional value of by-products through steam explosion

Antoniel Franco, Rex Newkirk, the University of Saskatchewan, Saskatoon, SK

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Key Messages:

- ***A method to dehull canola seed was successfully developed using smooth rolls in a roller mill combined with air fractionation, resulting in improved nutritional profile and digestibility.***
- ***Using steam explosion to enhance the dehulling of canola seed is challenging because canola hulls are highly lignified and are resistant to delignification and fibre modification. Pre-treatment of hulls with water or alkaline solutions did not appear to improve the effectiveness of steam explosion and had negative consequences due to excess water handling and drying.***
- ***Improving the digestibility of canola meal using steam explosion or similar hydrothermal treatments was not feasible in this experiment due to the high-water absorption capacity of the meal.***

Key words: canola; seed; meal; hulls; nutritional value; steam explosion; dehulling

Canola production and processing create significant economic benefits for Saskatchewan and Canada as a whole. The industry has grown over the years due to the demand for healthy oil, sound agronomy and suitable growing conditions in Saskatchewan. One of the challenges for the industry, however, is capturing maximum value from canola by-products such as canola meal.

Canola meal comprises approximately 60% weight of the original seed and is widely used in livestock production as an important source of protein. However, the meal is discounted relative to that of soybean meal due to low digestible energy in the meal. In addition, lower amounts of meal are exported due to limited maximum inclusion levels of canola meal in livestock diets. Canola hulls contain significant quantities of highly lignified fibre that appears to encapsulate nutrients and impairs their digestion by animals, especially monogastric species such as poultry and swine. To improve the value of canola meal and create greater market demand, it is important to increase the energy content of canola meal.

Although a few approaches, including producing yellow seeded varieties with less lignified fibre, adjusting processing conditions, and enzyme application, have been tested to improve meal energy content, the results from the majority of these methods showed limited impact on energy utilization in feeds. One option yet to be explored is the delignification and degradation of fibre through stream treatments such as stream explosion. This process was originally developed to increase the fibre digestibility in ruminants but is now mainly adopted by the cellulosic ethanol industry to pre-treat very low quality highly lignified materials, rendering them fermentable. During this process, the feed stock is exposed to high temperature and pressures in the form of steam pressure. This combination of high temperature and pressure, delignifies the material as well as degrades a large part of the hemi-cululose. In addition, the moisture that is forced into the microstructure of the cellulose rapidly turns into steam when the pressure is rapidly released breaking apart ("exploding”) the cellulose from within. As a result of this process, straw and wood products, that are otherwise indigestible, become in large part digestible and fermentable for ethanol production. Therefore, steam explosion was evaluated in this research as a way to make canola nutrients more available for digestion and absorption as well as increase the digestibility of the fibre fractions.

A three-year study was conducted by University of Saskatchewan researchers to study ways to improve the digestibility of high fibre canola products such as seed, meal and hulls using steam explosion technology combined with or without pre-treatments. In this experiment, industrial use of steam explosion processing with high temperature was modified by using pre-treatments with low temperature to minimize protein damage within seed and meals. The hulls proved to be resistant to steam explosion, so a more extreme set of treatments with high temperature and pressure were applied. Two types of pre-treatments were tested on canola seed, meal and hulls. In pre-treatment one, products were simply presoaked with water prior to steam explosion to allow increased water absorption into the fibrous matrix to improve the efficiency of steam expansion within the fibre during the decompression phase. The soaking can also serve to “soften” the fibre to make it more susceptible to steam explosion. In pre-treatment two, products were pre-soaked in an alkaline solution which serves to dissolve a portion of the lignin to increase the effectiveness of the process at reduced temperatures. A range of pre-treatments, pressures and durations were tested (Table 1). A digestibility study using broiler chickens was conducted to determine the effect of steam explosion on digestibility of nutrients in canola and hull fractions before and after dehulling.

A wide range of treatments were included to use canola meal as the initial starting point to approximate steam explosion of meal obtained from the desolventizer/toaster step from canola crushing plants. Research results showed that steam explosion of canola meal is not effective due to the high levels of water absorbed during the process. The process was less effective even with multiple attempts of reduced meal moisture content. High temperature extrusion with a single screw extruder may be a more effective method of hydrothermally treating canola meal or similar product.

Table 1. Summary of processing treatments tested by canola seed and product type

Product	Analysis	Pre-treatment	Pressure (PSI)	Time (min)
Meal	Composition	30% H_2O	100-300 (increments of 20)	5
Meal	Composition	20% H_2O	200-300 (increments of 20)	5
Meal	Composition	1.5, 2 & 2.5 X water	50, 100, 150	4
Seed	Composition	20% H_20	200 – 300 (increments of 20)	5
Seed	Composition	none	100 &160	2 & 5
Seed	Digestibility Broilers	Expelled Meal		
Seed	Digestibility Broilers	De-hulling, expelling		
Seed	Digestibility Broilers	Untreated		
Seed	Digestibility Broilers	Water Treated		
Seed	Digestibility Broilers	Exploded	180	5
Seed	Digestibility Layers	Untreated		
Seed	Digestibility Layers	Water Treated		
Seed	Digestibility Layers	Exploded	180	5
Hulls	Composition	none	160, 180, 200	2, 5 & 10
Hulls	Digestibility Broilers	Dehulling		
Hulls	Digestibility Broilers	Exploded	250	5
Hulls	Digestibility Broilers	Just Water	250	5
Hulls	Digestibility Broilers	Water & 3.5% NaOH	250	5

Improving nutritional value of canola by dehulling is effective, but dehulling canola seed through steam explosion is challenging. This is because the extensive lignification of canola hulls makes them resistant to delignification and fiber modification. Pre-treatment of hulls by either soaking in water or NaOH solution for 24 hours did not appear to improve the effectiveness of steam explosion and has negative consequences due to excess water handling and drying. In addition, the high temperatures that canola hulls encountered in this process appeared to produce antinutritional compounds that decreased digestibility by broiler chickens. According to the digestibility study conducted on broiler chickens, inclusion of steam exploded canola hulls in the diet at 6% inclusion level significantly reduced the apparent metabolizable energy (AME), dry matter digestibility and Energy digestibility and tended to decrease it when included at 12% inclusion level (Table 2). Pre-treating with water or basic solutions tended to reverse some of the losses in digestibility but the difference was not statistically different (Table 2). The reasons for a loss in dry matter and energy utilization after steam explosion is not apparent, but it is possible that degradation products of lignin during the process impaired digestion. It is interesting that steam explosion caused the greatest reduction in neutral detergent fibre (NDF) but also had the greatest negative impact on digestibility. Based on this evidence it would suggest significant modification of canola hulls by extreme hydrothermal treatments can have negative consequences on digestibility.

Table 2. Effect of treatments on the digestibility of diets containing canola hulls in broiler chickens of dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and apparent metabolizable energy (AME) on a DM basis

Treatment	AME (kcal/kg)	Gross Energy	DM
		6% Inclusion	
Canola Hulls	3442[a]	71.6[a]	66.4[a]
Steam Exploded[a]	2631[b]	54.1[b]	45.2[b]
Steam Exploded + water[b]	3098[ab]	63.3[ab]	55.8[ab]
Steam Exploded + base[c]	3156[ab]	64.4[ab]	57.1[ab]
SEM	172	3.5	4.3
P Value	0.0313	0.0239	0.0237
		12% Inclusion	
Canola Hulls	3303	67.6	61.9
Steam Exploded[a]	3127	63.4	58.2
Steam Exploded + water[b]	3218	65	59.3
Steam Exploded + base[c]	3349	68	62.1
SEM	78.8	1.6	1.9
P Value	0.2428	0.1771	0.3909

Values in the same column with different letters are significantly different at P<0.05

Note: *[a]Hulls steam exploded at 250 PSI for five minutes; [b]Hulls soaked in water at 2.5:1 ratio by weight (solution: product) and soaked for 24 hours then steam exploded at 250 PSI for five minutes; [c]Hulls soaked in NaOH at 2.5:1 ratio by weight (solution: product) and soaked for 24 hours then steam exploded at 250 PSI for five minutes.*

After the application of steam explosion treatments on canola hulls with little success, researchers developed a different method to dehull canola. According to this method, canola can be dehulled with relative ease using smooth rolls in a roller mill combined with air fractionation; it is necessary to dry canola to 10% in order to achieve effective dehulling. The whole process consisted of drying the seed, cracking using a roller mill equipped with smooth rolls (reduction or flaking rolls), separating the hulls from the embryo using air fractionation and further purification of the hulls using sieving. Removing the hulls with this method showed significant improvement in the nutritional content and digestibility of the remainder of the canola meal.

In conclusion, this research successfully developed a method to dehull canola seed to improve the nutritional content and digestibility of canola meal.

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Note:

This research was conducted on canola, camelina and Flax, but this summary is focused only on canola. The results for all oilseed products included are provided in the final long report.