ESTABLISHMENT OF CARINATA MEAL AS A PROTEIN SUPPLEMENT FOR BEEF CATTLE.

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ABSTRACT

The objective of this research was to evaluate the value of carinata meal (CRM) relative to canola meal (CM) when fed alone or in combination with wheat-dried distillers grains with solubles (WDDGS) on the performance of growing and finishing beef steers and rumen fermentation, total tract nutrient utilization, omasal flow and N efficiency of growing beef heifers. The first trial involved a 97-d backgrounding (BK) trial that used 360 calves (321.8 ± 0.10kg) assigned to one of 12 pens. Diets compared CRM relative to CM at two dietary inclusion levels (7.5 and 15% DM basis). The second trial was a finishing trial using 250 crossbred steers (418.7 ± 0.48 kg) assigned to 25 pens with five treatments: CRM (4.8% DM), CM (6% DM), WDDGS (6.2% DM), and CRM (2.7% DM) + WDDGS (2.7% DM) or CM (3% DM) + WDDGS (3% DM). Trial three designed as a Latin square, used 4 rumen-cannulated heifers (385.8 ± 27.95 kg) that were fed a barley-based BK diet supplemented with CRM (9.24% DM); CM (9.97% DM); CRM (4.98% DM) + WDDGS (5.03% DM) or CM (4.98% DM) + WDDGS (5.03% DM). In Trial 1 and 2, there were no differences ($P > 0.05$) between treatments for final shrunk BW or ADG, DMI and G:F. In trial 2, cattle fed CM had heavier hot carcass weights and a greater dressing percentage (DP) than those fed CRM diets. In Trial 3, apparent digestion of N tended ($P = 0.09$) to be greater for CRM and CM diets relative to WDDGS diets. The inclusion of WDDGS increased ($P = 0.04$) N truly digested in the rumen, and decreased ruminal non-ammonia nitrogen (NAN) flow. No treatment differences ($P > 0.05$) were noted in total bacterial NAN flow or in microbial efficiency. Carinata meal is equal to CM as a protein source for beef cattle without affecting performance, rumen fermentation, total tract nutrient utilization, and N efficiency. However, HCW and DP were greater in cattle fed CM relative to those fed CRM. There was no benefit to adding WDDGS as a rumen undegradable protein source.

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LIST OF ABBREVIATIONS

AA	Amino acid
ADF	Acid detergent fiber
ADG	Averaged daily gain
ADICP	Acid detergent insoluble crude protein
ADIN	Acid detergent insoluble nitrogen
BK	Backgrounding
BUN	Blood urea-N
CHO	Carbohydrate
CCM	Canola meal
CRM	Carinata meal
CP	Crude protein
Cr-EDTA	Chromium- Ethylenediaminetetraacetic acid
D	Potentially degradable fraction
DGGS	Dried distiller's grains with solubles
DM	Dry matter
DMI	Dry matter intake
EE	Ether extract
FAB	Fluid associated bacteria
FP	Fluid phase
G:F	Gain: feed
GIT	Gastrointestinal tract

HCW	Hot carcass weight
iADF	Indigestible acid detergent fiber
iNDF	Indigestible neutral detergent fiber
LPP	Large particle phase
MP	Metabolizable protein
MPS	Microbial protein synthesis
N	Nitrogen
NAN	Non-ammonia nitrogen
NANBN	Non-ammonia non-bacterial nitrogen
NDF	Neutral detergent fiber
NDICP	Neutral detergent insoluble crude protein
NDIN	Neutral detergent insoluble nitrogen
NH_3-N	Non-protein nitrogen
NE_g	Net energy of gain
NE_m	Net energy of maintenance
OM	Organic matter
OMTDR	Organic matter truly digested in the rumen
OTD	Omasal true digesta
Pab	Particle associated bacteria
PDV	Portal drained viscera
PP	Particle phase
RDP	Rumen degradable protein
RUP	Rumen undegradable protein

S	Soluble fraction
SBM	Soybean meal
SP	Soluble protein
SD	Standard deviation
SE	Standard error
SPP	Small particle phase
U	Undegradable phase
UUN	Urine urea-N
VFA	Volatile fatty acid
WDDGS	Wheat dried distiller's grains with solubles
$YbCl_3$	Ytterbium chloride

1.0 GENERAL INTRODUCTION

Brassica carinata or *Ethiopia mustard* is a member of the Brassica family. It originated in Ethiopia, being one of the oldest oilseed crops in Africa (Alemayehu et al. 2002). Members of this family are commonly cultivated in the southern prairies of Canada and the northern plains of the United States (Agrisoma Biosciences Inc. 2015). Plants are characterized by high oil (Agrisoma Biosciences Inc. 2015) and protein content, and relatively low crude fiber concentration (Getinet et al. 1996).

Increasing need for renewable fuel in North America has created new opportunities for non-food oilseed crops. Oil from carinata is an industrial oil not an edible oil, as is the case with canola. Its primary industrial use is as a source for bio-fuel production for the aviation industry (Agrisoma Biosciences Inc. 2015). Biodiesel made from renewable biological sources such as vegetable oils and animal fat are alternatives to more conventional diesel fuel. Carinata oil is suited to conversion to a biofuel that can simply replace all or part of the fuel for aviation engines. As carinata is an industrial source oil, it does not impact the human food chain as would biofuel from canola oil. As well, carinata plants grow well in dry semi-arid production regions and thus do not compete for the same land base as canola, which has a high protein by-product meal conventionally used in livestock rations (Agrisoma Biosciences Inc. 2015).

In terms of by-products, canola meal and wheat dried distillers grains with solubles (DDGS) are established sources of protein for dairy (Brito and Broderick 2007; Chibisa et al. 2012) and beef cattle (McKinnon and Walker 2009; Beliveau and McKinnon 2008 & 2009; Nair et al. 2015). Limited data is available on the use of carinata meal as a protein source for feedlot cattle. A preliminary in vitro trial conducted by Xin and Yu (2013) reported that carinata meal is higher in CP (48 vs. 40%) and lower in NDF (19 vs. 27%) and ADF (11 vs 18%) than canola meal.

Also, McKinnon et al. (unpublished) found no differences for growing performance when feedlot steers were fed carinata meal compared to canola meal. However, during the adaptation phase the yearling steers suffered feed intake issues. The authors speculated that this occurred due to the fact that the source of carinata meal used in this trial contained high levels of glucosinolate (>100umoles). Subsequently, Agrisoma Biosciences Inc. has produced carinata meal with reduced levels of glucosinolate (<30umoles) through processing using the desolventizing and toasting phase of pre-press solvent extraction with hexane seed. These levels are comparable to conventional canola meal. Thus, the protein value of low glucosinolate carinata meal needs to be evaluated. There is no published data on the comparison of carinata meal and canola meal as protein supplements for growing and finishing beef cattle.

Since carinata is suitable to be produced in semi-arid regions, it is a prospective crop for grain producers in the drier zone of Saskatchewan. Carinata grows well on poor lands that do not support a beneficial return from conventional food crops. As such, carinata has a lower cost of production. Therefore, carinata has economic advantages compared to growing traditional canola meal for the dry areas of the province of Saskatchewan.

The objectives of the following literature review are to provide an overview of nutrient composition, protein value and N metabolism of carinata meal relative to established protein sources for beef cattle, particularly with respect to feedlot performance and carcass quality.

2.0 LITERATURE REVIEW

2.1 Agronomic Characteristics and Seed Quality of Carinata versus Canola

Carinata is an Ethiopian oilseed crop from the *Brassica* family that has agronomical advantages such as high yield, tolerance to salinity and resistance to diseases such as blackleg, shattering, and excessive drought and heat (Rakow and Getinet 1998). These characteristics make carinata competitive with respect to conventional oilseed mustard crops cultivated in western Canada such as Brassica *rapa* and *B. napus* (Rakow and Getinet 1998). Getinet et al. (1996) in an early investigation about Ethiopian mustard grown in Saskatchewan reported that carinata seed had higher protein and lower oil and fibre concentration than canola seed. These authors also found that yellow seeded B. carinata contained a higher oil, and protein content, and lower fibre value than brown seeded B. carinata varieties. In addition, carinata seed had higher anti-nutritional compounds such as glucosinolates (119.8 umol/g) and erucic acid (42.1%). Both these compounds can negatively affect cattle health (Getinet et al. 1996; Warwick et al. 2006). However, the type of seed processing which uses high temperature as in pre-press solvent extraction has resulted in a meal with lower glucosinolate levels (Newkirk et al. 2003b). Therefore, the recent development of carinata meal with low anti- nutritional compounds make this high protein feedstock more attractive to livestock producers in North America.

2.2 Oil Seed Processing

Carinata, like other oilseed crops such as canola, can be processed into two fractions (crude feedstock oil and a high protein and low fibre meal) using one of three different methods: pre-press solvent extraction, double pressing and cold pressing (Newkirk et al. 2003b). Canola seed is primarily processed by pre-press solvent extraction with hexane. This method is outlined in

Figure 2.1. The process includes seed cleaning, drying, conditioning, flaking, expelling, cooking, solvent extraction with hexane, desolventization/toasting, drying and cooling, respectively (Newkirk et al. 2003b). The cleaned seed is flaked in order to rupture the cell wall without affecting the quality of the oil. Seed flakes are then cooked at a temperature of 80 to 90°C for 15 to 20 min to thermally rupture the oil cells. Using a screw press or expeller, the cooked flakes are pressed to remove 50 to 60% of the oil from the seed. Following this, the seeds are solvent-extracted with hexane to remove the remaining oil. The final steps, desolventizing and toasting the meal at 95 to 115°C are carried out in order to remove the hexane and reduce the moisture content to about 12% (Canola Council of Canada). Pre-press solvent extraction with hexane produces close to 100% extraction of the oil (Newkirk et al. 2003b).

This compares to approximately 90% oil removal with double or cold pressing. Using the double pressing method, the oilseed is processed similar to the pre-press solvent extraction process. The seed is expelled twice in order to remove the oil. This process eliminates some pre-press solvent extraction steps such as solvent extraction, desolventization, drying and cooling. During cold pressing, the seeds are never heated at temperatures above 60°C, they are only mechanically pressed. Since the meal is not desolventizied or toasted, protein quality is higher in meal derived from the double or cold pressing methods (Newkirk et al. 2003b).

Variation in oilseed processing can have an influence on meal quality (Newkirk et al. 2003b). Excessive heating during processing can induce losses in the content and digestibility of amino acids in the meal. Newkirk et al. (2003b) reported that in Canadian crushing plants during the desolventizer–toaster phase, crude protein and lysine digestibility decrease as well as lysine content. Inclusion of some by-products of processing such as soapstocks and gums will improve

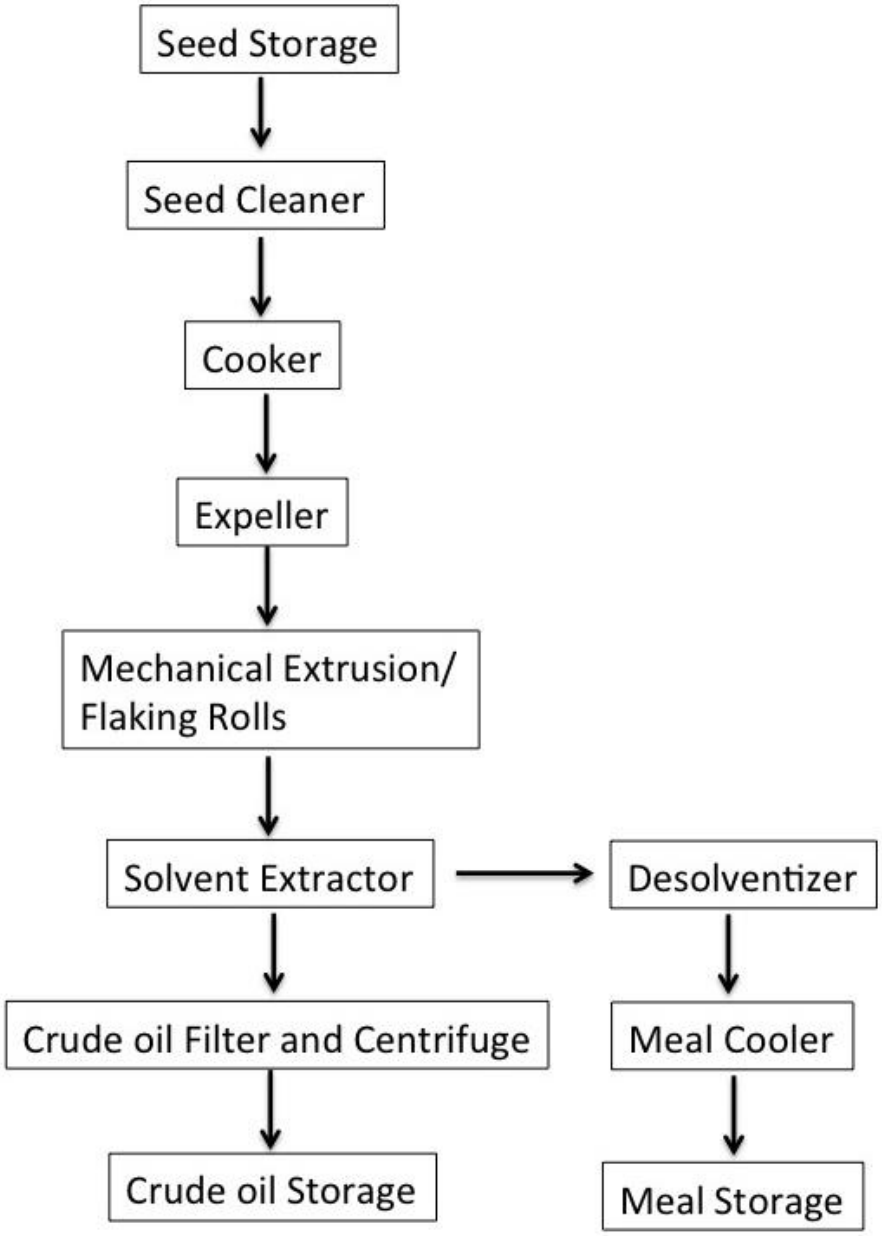

Figure 2.1. Prepress solvent extraction process (adapted from Canola Council of Canada).

the energy content of the meal. However, the meal quality can be reduced by the inclusion of by-products such as foreign material and screenings. Therefore, good processing control and high quality ingredients should be adopted to avoid changes in the value of the meal.

Other high protein livestock feeds used in North and South America such as WDDGS and SBM are co-products from biodiesel production and food processing. High-energy grains such as wheat and corn are processed for ethanol production. Grinding, cooking, liquefaction, scarification, fermentation and drying compose this process (Bothast and Schlicher, 2005). The oil extraction of soybean is similar to conventional canola crush infrastructure by using solvent extraction process. However, the seed is not expelled as in the canola processing (Shi and Bao, 2008). The final products from ethanol production are biofuel, DDGS and carbon dioxide. Whereas from biodiesel production they are biofuel and soybeans or canola meal. (Spiehs et al. 2002; Shi and Bao, 2008; Newkirk et al. 2003b).

2.3 Nutritional Characteristics of Carinata Meal Relative to Other Common Protein Sources for Feedlot Cattle

In comparison with canola, which has been shown to be an effective supplementary protein source for livestock (McKinnon and Walker, 2009), carinata seed has higher protein and lower crude fiber content (Getinet et al. 1996). Similar to canola, factors such as seed and meal processing, type of seed, and to a minor extent, environmental conditions during plant growth likely affect nutrient composition of carinata meal (Simbaya et al. 1995). For example, Getinet et al. (1996) reported that yellow colored *Brassica* carinata provides heavier seed (+0.4g), higher protein (+21 g kg^{-1}) and oil (+23 g kg^{-1}), and lower fiber content (-12 g kg^{-1}) than brown colored

Brassica carinata. Simbaya et al. (1995) showed that yellow seeded Brassica carinata meal contains 52.6 versus 48.8% protein in comparison with brown seeded *Brassica* carinata meal.

2.3.1 Crude Protein

There is a lack of information about the use of carinata meal as a protein supplement in animal production. However, some reports suggest that carinata meal is higher in crude protein content relative to canola meal (Table 2.1). Xin and Yu (2013) reported that carinata meal had a CP content of 48% compared to 40% CP in canola meal. Similarly, McKinnon et al. (unpublished) reported higher (52.7 vs. 41%) CP content in carinata meal relative to canola meal. When comparing canola meal to soybean meal, Bell (1993), reported that SBM (48.1 vs. 38.29% CP) was a superior CP source.

Numerous reports have established canola meal and grain based by-products such as WDDGS as protein supplements for the livestock industry (Gozho et al. 2008; Beliveau and Mckinnon 2008 and 2009; Mulrooney et al. 2009; He et al. 2013). Xin and Yu (2013) noted that canola meal had 40% CP, a value similar to that reported by Bell et al. (1993 & 1998) and Newkirk et al. (1997). In terms of grain based by-products, WDDGS has higher (44.5 vs. 30.3%) CP content than corn DDGS (Widyaratne and Zijlstra, 2007). If one compares canola (57.4% RDP) and carinata meal (74.5% RDP) to other high protein by-products such WDDGS (45.6% RDP) or corn DDGS (32% RDP), canola (42.6% RUP) and carinata (25.5% RUP) meal tends to be more degradable in the rumen and thus is not as a good source of rumen undegradable protein (NRC, 2016; Xin and Yu 2014; WDDGS Feed Guide, 2013). However, recent findings suggest that canola meal has significant RUP content and it is higher in comparison with WDDGS and corn DDGS (Mutsvangwa, 2017). Maxin et al. (2013a) reported that neutral detergent insoluble

Table 2.1. Examples of Chemical Composition (Mean±SD) of Common western Canadian Protein Sources for Cattle based on Published Literatures.

Nutrient	CarinataMeal[1,2]	CanolaMeal[1,2,3,4,7]	WheatDDGS[5,6,7]	SoybeanMeal[3,7]
DM (%)	93.3	92.0	91.3	89.6
CP (% DM)	50.4	39.3	39.0	50.4
RDP (% CP)	74.5	61.2	45.6	70.4
RUP (% CP)	25.5	38.6	54.4	29.4
NDF (% DM)	17.6	25.3	46.4	9.2
ADF (% DM)	10.0	18.8	14.1	6.2
EE (% DM)	2.9	4.1	5.8	1.3
Ca (% DM)	…	0.65	0.18	0.36
P (% DM)	…	1.06	0.96	0.70

Note: Adapted from: Xin and Yu 2013 and 2014[1]; McKinnon (unpublished)[2]; NRC, 2016[3]; Canola meal Feed industry Guide -5th Edition, 2015[4]; Wheat DDGS Feed Guide -2st Edition, 2013[5]; McKinnon and Walker 2008[6]; Bell 1993[7].

crude protein (NDICP) which is a ruminally-undegradable protein predictor, was 16.7% for canola meal, 9.1% for WDDGS and 8.8% of CP for corn DDGS. Therefore, comparing earlier researches with more recent studies, ruminal degradability for canola meal (51.5 vs. 44%) decreased as for WDDGS increased (45.6 vs. 60.8%) (Kendall et al.1991; Hedqvist and Uden, 2006; Nuez-Ortin and Yu. 2010; Maxin et al. 2013b). The variation in the nutrients composition and degradability of protein sources relative to early studies could be attributed to growing conditions, storage, variation in processing as the addition of hulls and foreign material resulting in the dilution of the meal (Bell, 1993; Newkirk et al. 2003b).

The main goal of dairy and beef cattle industry is provide an appropriate balance between RDP and RUP in order to obtain rumen nitrogen (N) levels that are necessary to improve microbial crude protein synthesis and to optimize the absorbed metabolizable AA profile (NRC, 2016). Since canola meal is source of RDP, it can help meet the N requirements of the rumen microorganisms (McKinnon et al. 1991; Boila and Ingalls, 1994b; McAllister et al. 1993; Gozho et al. 2008). Grain based by- products such as WDDGS that are used as a source of RUP have been shown to improve the flow of AA into the small intestine of dairy cows (Chibisa et al. 2012). Carinata meal being a relatively good source of RDP is thus a potential feed ingredient that when fed alone or in combination with a source of RUP (WDDGS) can serve as a protein supplement for growing and finishing cattle.

2.3.2 Fiber

Neutral detergent (NDF) and acid detergent fiber (ADF) are considered as constituents of the cell wall of plants and are often referred to as structural carbohydrates, although technically this lignin component is not a carbohydrate (NRC, 2016). Being composed of cellulose,

hemicellulose and lignin, NDF is not the highest digestible feed component particularly compared to other nutrients such as starch or CP (NRC, 2016). In addition, NDF has been suggested to be a good predictor of voluntary DM intake due to its fill capacity (Mertens, 1997). Because ADF is the least digestible feed fraction due to its cellulose and lignin content, it is negatively related with forage digestibility (NRC, 2016). As a consequence, NDF and ADF levels in feedlot rations have been a concern to nutritionists, since they are associated with lower dietary energy content (NRC, 2016). Carinata meal has a lower concentration of NDF and ADF compared to canola meal (Xin and Yu. 2013). Getinet et al. (1996), reported that the weight of an oilseed seed is positively related with the amount of oil and protein and negatively associated with its fibre concentration. Xin and Yu (2013) found the NDF (19 ± 2.4 vs. 28% ± 2.4%) and ADF (11 ± 1.8 vs. 19% ± 1.8%) content of carinata meal was lower compared to canola meal. Mckinnon et al. (unpublished) also reported carinata meal had lower NDF (16 vs. 27%) and ADF (8.8 vs. 20%) relative to canola meal. Bell (1993) compared NDF (21.54 vs. 7.1%) and ADF (17.47 vs. 5%) values for canola meal to soybean meal, respectively and found that canola meal had higher fibre values than SBM, mainly due to the seed coat (hull). Thus, these findings suggest that rations with carinata meal as a protein supplement contain a superior level of energy and protein compared to rations formulated with canola meal.

2.3.3 Fat

Although there are no data on bioavailability of fatty acids of carinata seed for beef and dairy cattle, it is a source of unsaturated fatty acids. Carinata seed is relatively high in linoleic (19.9 vs. 19.4%) and linolenic (10.8 vs. 9.8%) and erucic (40.6 vs. 2.4%) and low in oleic (13.0 vs. 61.4%) fatty acids in comparison with “double - zero” canola seed (Mnzava and Olsson, 1990).

The type of extraction process to remove the oil from the seed determines fat content of the meal. Canola meal after pre-press solvent extraction contains less than 1 to 3% oil (Newkirk et al. 2003b). However, other methods of extraction such as double pressing and cold pressing leave 10 to 20% oil in the meal (Newkirk et al. 2003b). With canola some additives such as gums can influence the amount of fat in the meal. These can be added in the desolventizer-toaster phase at a level of 1 to 2%, increasing the final fat content of the meal (Bell, 1993).

Comparing the chemical composition of carinata versus canola meal, Xin and Yu (2013) showed that EE (2.17%) was not statistically different between meals. Mckinnon et al. (unpublished) in a preliminary trial about the evaluation of carinata meal as a protein supplement for yearling steers observed that EE of carinata meal was 3.8% while the same chemical component of canola was 3.5%. Bell (1993) reported EE values (3.6 vs. 0.7%) for canola meal relative to soybean meal. The fat present in the meal has the potential to impact the NE_g content, increasing feed efficiency (NRC, 2016).

2.3.4 Minerals

There is a lack of information about the mineral profile of carinata meal. However, canola meal and WDDGS are established sources of minerals (Bell 1993; Nair et al. 2105; Walter et al. 2012; Beliveau and Mckinnon 2008). Bell (1993) reported that canola meal was superior in calcium (0.64 vs. 0.30%) and phosphorus (1.03 vs. 0.65%) in comparison with SBM. Nair et al. (2015) evaluated two types of canola meal as an energy source for feedlot steers and found that calcium values were 0.79% for B. *napus* and 0.8% for B. *juncea* meal and the phosphorus levels averaged 1.2% (DM basis). Canola meal and WDDGS are high in phytate P which is not digested by non-

ruminants. However, phytate P is digested by ruminants due to the presence of the phytase enzyme in rumen bacteria (NRC, 2016).

2.3.5 Amino Acids

The amino acid profile of defatted carinata meal and "double zero" canola meal are illustrated in Table 2.2. In terms of essential amino acids, carinata meal is higher in arginine (10.8 vs. 7.6% CP) and lower in leucine (6.8 vs. 7.3% CP), lysine (4.3 vs. 5.1 %CP), valine (4.9 vs. 5.6% CP), methionine (1.8 vs. 2.1 % CP), and cysteine (2.0 vs. 2.4% CP) in comparison to canola meal (Mnzava and Olsson, 1990; Pedroche et al. 2004; Newkirk, 2009). Relative to nonessential amino acids carinata meal is higher in glutamic acid (20.7 vs. 17.9% CP) and lower in alanine (3.8 vs. 4.3% CP), aspartic acid (6.6 vs.8.1 %CP), and proline (6.5 vs. 6.1 %CP) than canola meal (Mnzava and Olsson, 1990; Pedroche et al. 2004). However, further studies are required in order to determine carinata meal amino acid digestibility in dairy and beef cattle.

2.4 Rumen Fermentation of Feedstuffs

Beef cattle need amino acids for maintenance and production purposes (NRC, 2016). Protein is supplemented in animal diets in form of crude protein (N x 6.25). Dietary CP is degraded to a variable extent by rumen microbes such as proteolytic bacteria (e.g. *Streptococcus bovis*), fibrolytic bacteria (e.g. *Fibrobacter succinogenes*) and to a lesser extent by protozoa (e.g. *Entodinium caudatum*) to ruminally degradable (RDP) and undegradable protein (RUP; Ørskov, 1979). Being the major source of N for microbial protein production, RDP is comprised of true preformed protein (peptides and amino acids) and nonprotein nitrogen (NH_3-N) (Bach et al. 2005). Although rumen microbes do not degrade RUP, it can be extensively digested in the

Table 2.2. Amino acids Profile of Carinata versus Canola Meal.

Item	Carinata Meal[1,2]	Canola Meal[1,2,3]
CP (%DM)	47.6	38.7
Essential Amino Acid (%CP)		
Arginine	10.8	7.6
Leucine	6.8	7.3
Lysine	4.3	5.1
Valine	4.9	5.6
Methionine	1.8	2.1
Cysteine	2.0	2.4
Nonessential Amino Acid (%CP)		
Glutamic	20.7	17.9
Alanine	3.8	4.3
Aspartic acid	6.6	8.1
Proline	6.5	6.1

Note: Adapted from: Mnzava and Olsson, 1990[1]; Pedroche et al. 2004[2] and Newkirk (2009)[3].

abomasum and intestine (Chibisa et al. 2012). The amount of NH_3-N used for microbial protein synthesis depends on the availability of energy required to drive microbial protein synthesis (Nocek and Russell, 1988).

Microbial efficiency is dependent on the balance between protein and dietary energy, since this association determines the rate of microbial growth optimizing the use of N in the rumen. For instance, limiting dietary RDP intake relative to dietary fermentable carbohydrate (CHO) supply can reduce microbial growth and consequently MPS. Conversely, limiting CHO supply relative to dietary RDP also negatively affects microbial efficiency (Chibisa et al. 2012; Hristov et al. 2005). Hristov et al. (2005) reported a positive relationship between CHO and NH_3-N incorporated into MP. In addition, an adequate CHO supply helps to ensure that AA from the diet are used directly for MPS instead of being used for NH_3-N production (Russel et al. 1983; Chibisa et al. 2012).

Excessive NH_3-N (i.e. when feed protein intake is excessive and energy is limiting) that is produced in the rumen and not captured as microbial protein is absorbed across the ruminal wall and PDV to be detoxified to urea by the liver (Chibisa et al. 2012). Subsequently, the urea is released into blood (BUN) and can follow two paths. First, it can be recycled by the GIT, especially into the rumen as NH_3-N. Once in the rumen this recycled urea-N can serve as NH_3-N for microbial protein synthesis and metabolizable amino acids supply (Hristov et al. 2011a). Secondly, the blood urea-N (BUN) can be excreted in urine as urea-N (UUN) (Hristov et al. 2011a). Consequently, as protein is the most expensive ingredient in livestock diets, the major goal of nutritionists is to achieve a balance between N intake and fermentable CHO to enhance capture of NH_3-N and AA into microbial protein and reduce losses of urea-N in urine.

2.4.1 Optimizing Microbial Protein Synthesis

Several factors such as N and energy supply, retention time and ruminal pH are important determining factors for optimizing the use of NH_3-N in the rumen (Chibisa et al. 2012). For instance, N metabolism is dependent on the synchrony in RDP and fermentable energy supply to provide for microbial growth and MPS (Chibisa et al. 2012). For example, when a feed source with increased retention time due to high NDF is fed, ruminal pH value increases and ruminal NH_3-N concentration decreases (Bach et al. 2005). Therefore, optimizing NH_3-N utilization by microbes can improve MPS increasing uptake of metabolizable protein in the small intestine and decreasing losses as urea-N in urine (Broderick 2003; Hristov et al. 2005; Chibisa et al. 2012).

2.4.2 Ruminally Degradable Protein vs. Ruminally Undegradable Protein

Ruminally degradable protein (RDP) is the main source of rumen NH_3-N, which is the most important precursor for microbial growth and microbial protein synthesis particularly that of cellulolytic bacteria (Reynal et al. 2005). Microbial protein synthesis is essential to increase nonammonia nitrogen (NAN) flow through the small intestine (Clark et al. 1992). Dietary supply of RDP is critical to enhance microbial nonammonia nitrogen (NAN) flow from the rumen (Reynal et al. 2005; Brito et al. 2006). Reducing RDP from 3.01g/d to 2.47g/d reduced NAN flow from 465g/d to 423g/d (DM basis) (Brito et al. 2006). Also, Reynal et al. (2005), comparing four internal markers to measure microbial protein flow, reported that reducing RDP from 13.2 to 10.6% decreased NAN flow from 470g/d to 384g/d (DM basis) using ^{15}N as a microbial marker. However, dairy cows fed with high (11.6% DM) versus moderate levels of RDP (9.4% DM) showed no improvement in MPS, increasing N excretion as a consequence (Hristov et al.

2005). Therefore, optimization of RDP supply is necessary to enhance ruminal microbial protein synthesis.

While RDP is the portion of dietary CP (ruminal N) used for MPS, ruminally undegradable protein (RUP) is the CP fraction that bypasses the rumen, it is potentially available for absorption in the small intestine (Chibisa et al. 2012). Since RUP is not a source of N for microbial growth, it is required to balance the ratio between RDP and RUP in dairy and beef cattle rations in order to optimize animal performance (Santos et al. 1998; Wagner et al. 2010). This is due to the fact that RUP and its AA can be a complement to microbial AA that reach the small intestine and are absorbed as metabolizable protein to meet the animal's AA requirements for maintenance and production.

Nutritional programs such as the Cornell Net Carbohydrate and Protein System (CNCPS) are used to predict protein and dietary fermentable (CHO) fractions degraded in the rumen (Russel et al. 1992; Sniffen et al. 1992; Fox et al. 2004). This takes into account feed composition, digestion, and excretion as nutrient requirements and animal performance based on a rumen sub-model (Russel et al. 1992; Tylutki et al. 2008). The basis of this aspect of the model is the difference in the rate of degradation and the rate of passage between feed fractions (Russel et al. 1992; Sniffen et al. 1992; Fox et al. 2004; Tylutki et al. 2008).

Xin and Yu (2013) based on the CNPCS sub-model described in Sniffen et al. (1992) compared carinata to canola meal in terms of amino acids and CHO profile. The PA (rapidly degradable protein, k_d= infinity) and PB1 (rapidly degradable protein, k_d = 120-400% h^{-1}) fractions were higher in carinata meal (38.48 ; 17.13 %CP) than in canola meal (27.23 ; 7.54 %CP) fraction. However, PB2 (intermediately degradable protein, k_d = 3-16% h^{-1}), PB3 (slowly degradable protein, k_d = 0.06-0.55% h^{-1}) and PC (undegradable protein) fractions were lower in

carinata meal (34.87; 8.27 and 1.26% CP) compared to canola meal (48.09; 13.83 and 3.32% CP). The CA (rapidly fermented carbohydrate, k_d = 200-350% h^{-1}) and CB2 (slowly degraded carbohydrate, k_d = 2-10% h^{-1}) fractions were higher for carinata meal (61.36; 20.45% CHO) than for canola meal (52.78; 2.01% CHO). In contrast, CC (unavailable cell wall) was lower for carinata meal (18.20% CHO) compared to canola meal (45.22% CHO). This could be assumed that carinata meal has an increased rate of protein and CHO degradation relative to canola meal using the CNCPS.

Several CNCPS updates have been published (Van Amburgh et al. 2010 and 2013). In the CNCPS version 6.5, Van Amburgh et al. (2013) reported that the protein pool is portioned into PA1 (ammonia) with a degradation rate of 200%/h, PA2 (soluble non-ammonia CP) with a degradation rate of 10-40%/h, PB1 (moderately degradable CP) with a degradation rate of 3-20%/h, PB2 (slowly degradable CP) with a degradation rate of 1-18%/h and PC (unavailable CP) fractions. Carbohydrates are separated into CA1 (volatile fatty acids) with) 0% degradation, CA2 (lactic acid) with a degradation rate of 7%/h, CA3 (organic acids) with a degradation rate of 5%/h, CA4 (sugar) with the degradation rate of 40-60%/h. The CB1 (starch) and CB2 (soluble fiber) both with a degradation rate of 20-40%/h. The CB3 (available NDF) with a degradation rate of 4-9%/h and CC (unavailable NDF) with a determined value based on 240 h *in vitro* digestibility instead of ((lignin x 2.4)/NDF) estimated value (Raffrenato, 2011). Currently, there was no research done on protein and CHO degradability of carinata meal using the updated model of CNCPS.

2.4.3 Metabolizable Protein

Metabolizable protein (MP) is the absorbed AA from the small intestine (NRC, 2016). It is composed of microbial protein, RUP and endogenous protein (Chibisa et al. 2012; NRC, 2016). Endogenous protein is the CP secreted into the GIT as salivary, gastric, pancreatic and intestinal secretions plus sloughed cells (Chibisa et al. 2012). Supply of RUP at ideal levels has the potential to complement AA from rumen microbial synthesis to enhance animal performance (NRC, 2016). Excessive MP (AA) not required by the animal for maintenance or production is lost as a urea-N through urine (NRC, 2016). As a result, a balance between CP intake and animal nutrient requirements is necessary in order to increase performance and reduce cost and waste.

2.4.3.1 Metabolizable Protein Requirements

Metabolizable protein requirements for beef cattle are based on animal requirements used for maintenance, growth, pregnancy and lactation (NRC, 2016). The availability of metabolizable protein to animal tissues (net protein) is dependent on AA content of metabolizable protein absorbed across the small intestine (NRC, 2016). Since the mean biological value of protein is 66% (Armstrong and Hutton, 1975), NRC (1985) calculated a constant net protein for gain (0.50) and milk production (0.65). As well, NRC (2016) uses a predictor equation to measure the conversion of metabolizable protein to net protein for gain and milk production, which is negatively affected by animal body weight (NRC, 2016):

$$\text{MP to NP efficiency, \%} = 30+10{,}493.1 \times e^{(-0.0486 \times BW)}, \text{ RMSE}=13.2$$

Where e = (2.718).

2.5 Performance of Feedlot Cattle Fed Carinata Meal Relative to Other Common Protein Sources

Little information exists regarding the use of carinata meal in backgounding and finishing diets for beef cattle. A preliminary trial evaluated carinata meal as a protein supplement for yearling steers (McKinnon et al. unpublished). This trial used three treatments based on canola meal, carinata meal or a 50:50 blend of canola and carinata meal fed as protein supplements at 10% of the diet dry matter. The results indicated that during the first 42 days of the trial, the carinata meal-fed cattle had reduced rates of gain and poorer feed efficiency than either the canola meal or 50:50 carinata meal and canola meal fed steers. Dry matter intake was not significantly affected but was numerically lower during this phase for cattle fed carinata meal. Over the remainder of the trial, there was no effect of treatment with carinata meal fed steers compensating for the initial poor performance. The authors speculated that the initial poor performance may have been due to the relatively high glucosinolate levels (>127 μmoles) in the carinata meal (Table 2.3).

In contrast, canola meal has been well studied as an energy and protein source for growing and finishing beef and dairy cattle (Nair et al. 2015; Gozho et al. 2008; Petit et al. 1994; Mckinnon et al. 1991). Feedlot cattle fed 15% or 30% (DM basis) solvent extracted canola meal derived from *B. napus or B. juncea* as an energy source in barley grain-based diets did not have any effect on ADG in growing or finishing period (He et al. 2013). At the 30% inclusion level, canola meal supplementation resulted in a lower G:F ratio compared to 15% canola meal during the finishing period. The authors attributed this result to increased DMI (He et al. 2013). Nair et al. (2015) reported that in terms of energy, substituting barley-grain for 15 or 30% canola

Table 2.3. Literature Comparison of the Performance Feedlot Cattle Fed Carinata Meal Relative to other Common Protein Sources.

Protein Source (DM basis)		Average daily gain (kg d^{-1})	Dry matter intake (kg d^{-1})	Gain:Feed[1]
Backgrounding Diets				
McKinnon et al. (unpublished)				
Carinata Meal	10%	0.94	10.18	0.090
Canola Meal	10%	1.08	10.61	0.102
McKinnon and Walker (2009)				
Canola Meal	11.5%	1.32	9.3	0.140
Nair et al. (2015)				
Canola Meal (*B. Napus*)[2]	15%	1.59	8.96	0.178
	30%	1.59	9.03	0.176
Canola Meal (*B. Juncea*)[2]	15%	1.56	8.74	0.178
	30%	1.65	8.96	0.186
Gibb et al. (2008)				
WDDGS	20%	1.50	10.70	0.140
	40%	1.57	11.56	0.137
	60%	1.54	11.72	0.132
Finishing Diets				
Nair et al. (2015)				
Canola Meal (*B. Napus*)	10%	1.64	11.37	0.178
	30%	1.55	11.22	0.176
Canola Meal (*B. Juncea*)	20%	1.60	11.17	0.178
	30%	1.58	11.24	0.186

Note: Calculated based on shrunk B; *B.napus= Brassica napus; B.juncea= Brassica juncea.*

meal derived from B. *napus* or B. *juncea* had no effect on performance either in the growing or finishing period.

Yang et al. (2013) fed steers 10% canola meal (DM basis) and observed higher ADG and gain: feed than non-supplemented backgrounded steers. Williams et al. (2008) reported a lower ADG (1.60 vs. 1.70 kg d^{-1}) and DMI (10.23 vs. 11.39 kg d^{-1}) for feedlot steers fed a processed barley/canola meal pellet compared to a dry rolled barley-based diet containing 15 or 6% of canola meal throughout the trial. In addition, feed: gain was higher for cattle fed the processed barley/canola meal pellet through the finishing period (6.03 vs. 6.21 kg d^{-1}) and over the course of the total trial (6.27 vs. 6.64 kg d^{-1}). The authors concluded that the decrease in ADG and DMI (in backgounding and finishing phases) could be related to sub-acute rumen acidosis due to the use of the processed pelleted high grain diet.

There are numerous reports in the literature on the value of ethanol byproducts such as corn and wheat dried distillers' grains with solubles (DDGS) with respect to chemical profile and rumen degradability (Nuez-Ortin and Yu, 2009). As well, several studies have been done on the value of DDGS as a protein supplement in backgrounding diets (McKinnon and Walker, 2008) and as a protein and energy supplement in backgrounding and finishing diets, respectively (Beliveau and McKinnon 2008 & 2009). Backgounding steers fed WDDGS up to 50% of the diet (DM basis) showed an improvement in ADG and feed efficiency relative to those fed barley grain as an energy source (McKinnon and Walker 2008). Gibb et al. (2008) found similar DMI, ADG, and feed efficiency in backgounding cattle when WDDGS was fed as a replacement to barley grain at 20 or 40% (DM basis). However high inclusion levels of WDDGS (60% DM) in a barley- based diet decreased digestibility and energy content, resulting in a poorer feed efficiency and NE_g value of finishing diets (Gibb et al. 2008).

2.6 Carcass Characteristics Associated with Carinata Meal Feeding

In terms of carcass characteristics of feedlot cattle fed carinata meal as a protein supplement little research has been done. In the only study to date, McKinnon et al. (unpublished) reported that yearling steers fed carinata meal at 10% of the diet DM basis, showed no differences between treatments on ultrasound subcutaneous rib or rump fat thickness. In contrast, numerous studies have been conducted with canola meal (Williams et al. 2008; McKinnon and Walker 2009; Nair et al. 2015) and wheat-dried distillers' grains with solubles (Gibb et al. 2008; Beliveau and McKinnon 2008; Yang et al. 2012) with respect to carcass quality. McKinnon and Walker (2009) reported no effect of canola and mustard presscake from biodiesel at levels up to 10% DM basis on ultrasound measurements of longissimus dorsi area and subcutaneous fat depth. Nair et al. (2015) found that inclusion of canola meal at 10 and 20% (DM basis) as a source of energy for feedlot steers reduced the cattle grading Canada AAA *($P<0.05$).* He et al. (2013) reported no effect on carcass quality of cattle fed high dietary levels of canola meal (15 and 30% DM basis). With respect to WDDGS, Beliveau and McKinnon (2008) reported no differences in carcass traits with increasing levels of WDDGS up to 23% (DM basis). Yang et al. (2012) also found no effect on carcass traits when cattle were fed different levels of WDDGS (25, 30 and 35% DM basis) in barley based finishing diets, however liver abscess scores increased ($P < 0.01$) as WDDGS increased in the diet. Although, Gibb et al. (2008) found no differences with respect to dressing percentage in cattle fed WDDGS at 20 and 40% DM (basis), Walter et al. (2010), observed that dressing percentage linearly ($P < 0.01$) increased in feedlot steers fed up to 40% WDDGS (DM basis).

2.7 Techniques for Determining Fermentative Digestion in Ruminants

The nutritional value of ruminant diets can be evaluated using techniques that determine the rumen digestibility and intestinal supply of nutrients. In vivo methods such as the omasal sampling technique was developed to assure accuracy for ruminal digestion and outflow of feed ingredients from the rumen to the small intestine. The omasal sampling technique is used to estimate apparent and true ruminal digestibility and passage of nutrients out of the rumen (Huhtanen et al. 1997). Using this technique, a digesta sample is collected from the omasum via a ruminal cannula by a tube connected to a vacuum pump. This method has economic and functional advantages compared to techniques using duodenal and abomasal cannulated animals (Reynal and Broderick, 2003). Duodenal cannulation is more expensive, requiring an invasive surgery (Reynal and Broderick, 2003). Indigestible ruminal markers such as Cr-EDTA, YbCl and iNDF have been used in order to reconstitute different digesta phases as fluid, small and large particles, respectively (France and Siddons, 1986). Although indigestible ruminal markers are commonly used in association with the omasal technique to estimate ruminal outflow of nutrients, the utilization of markers could not be accurate if high fermentative diets are fed or as well when the concentration of the marker is not representative of the omasal digesta sample (Titgemeyer, 1997).

Total tract collection is an in vivo technique that has been traditionally used to determine apparent total tract digestibility. Utilizing this technique, total fecal DM output is collected in order to determine total tract digestibility based on intake of DM, corrected for orts, following the equation of (Corbett, 1978):

Apparent Total Tract Digestibility= DMI- DMO/DMI x100%

Laboratory analyses are conducted in order to determine the nutritional value of each digesta phase, and for the feed offered and feces collected. Subsequently, the amount of energy, protein and fiber true and apparent digested by the animals are determined using omasal and the total tract techniques, respectively. Internal indigestible markers as iADF and iNDF have been used to determine nutritional digestibility of diets in animals where total collection of urine and feces are not viable (Huhtanen et al. 1994). Weiss (1994) stated that total collection of feces and urine is the most accurate method to establish digestibility of forages in animals. However, Corbett (1978) reported that this technique has some disadvantages when faeces are collected from grazing animals in bags attached to a harness worn. For instance, the procedure can decrease animal performance, it is difficult to separate urine in females or measurements are not easy to be quantified.

2.8 Summary

The increased demand for alternative feedstocks for biofuel production make some oilseed crops such as *Brassica* carinata an interesting research subject. The primary industrial use for carinata is as an oil source for bio-fuel production for the aviation industry (Agrisoma Boisciences Inc. 2015). Due to the fact that carinata is an industrial oil and more productive agronomically in semi-arid regions, means that it does not compete for the same land base as canola (Agrisoma Boisciences Inc. 2015). Consequently, carinata meal, a by-product of oil processing has the potential to be a viable source of protein to beef and dairy cattle in the southern prairies of Canada and the northern plains of the US.

Relative to canola meal, carinata meal has a greater crude protein content and less fibre. Xin and Yu (2013) reported that carinata meal had a CP content of 48%, ADF and NDF levels of

11% and 19%, respectively and NE_m and NE_g values of 2.19 and 1.51 Mcal/Kg of DM. McKinnon et al. (unpublished) reported similar CP (52.7%), ADF (8.8%) and NDF (16.5%) values for carinata meal.

By way of comparison Xin and Yu (2013) noted that canola meal had 40% CP, 18% ADF and 27% NDF, values similar to that reported by Bell et al. (1993 & 1998) and Newkirk et al. (1997). If one compares carinata meal and canola meal to other high protein by products such WDDGS or corn DDGS, both tend to be more degradable in the rumen and thus are not as thought of good sources of rumen undegradable protein. Based on its chemical composition, particularly in relation to canola meal, Xin and Yu (2013) suggested that carinata meal is an excellent candidate as a potential protein supplement for growing and finishing cattle.

Common protein sources as canola and WDDGS have been very well established as a protein supplements for beef and dairy cattle (Nair et al. 2015; He et al. 2013; Gozho et al. 2008; Petit et al. 1994; Mckinnon et al. 1991; McKinnon and Walker, 2008; Beliveau and McKinnon 2008 and 2009). However, restricted data exist to evaluated carinata meal as a protein supplement in backgrounding and finishing diets for beef cattle.

2.9 Hypothesis and Objectives

2.9.1 Hypothesis

The hypothesis of the research carried out in this thesis was that due to its relatively high level of protein and low fiber content, carinata meal will be able to replace canola meal as a protein supplement in rations for growing and finishing beef cattle and as a result maintain or improve performance.

2.9.2 Objectives

The objectives of this research were to:

1) compare carinata meal to canola meal as a protein source in the diet of growing beef steers;

2) compare the value of carinata meal to canola meal as a protein supplement when fed alone or in combination with WDDGS in finishing rations of yearling steers;

3) measure the value of carinata meal relative to canola meal when fed alone or in combination with WDDGS on rumen fermentation, total tract nutrient utilization, omasal nutrient flow and N efficiency.

3.0 COMPARISON OF CARINATA MEAL RELATIVE TO CANOLA MEAL WITH OR WITHOUT WHEAT DRIED DISTILLER'S GRAINS WITH SOLUBLES AS A PROTEIN SOURCE FOR FEEDLOT STEERS.

Abstract

Two trials were conducted to evaluate carinata (CRM) versus canola meal (CM) as a protein source when fed alone or in combination with wheat-dried distillers grains with solubles (WDDGS) on the performance of feedlot cattle. Trial one was a 97-d backgounding (BK) trial that used 360 weaned steers (321.8 ± 24.3 kg; mean ± SD) assigned to one of 12 pens. Treatments compared CRM to CM at two inclusion levels (7.5 and 15% DM basis). Trial two was a finishing trial with 250 yearling steers (418.7 ± 26.7 kg) assigned to 25 pens with five treatments: CRM (5% DM); CM (5.9% DM); WDDGS (6.2% DM); and CRM (2.8% DM) + WDDGS (2.7% DM); or CM (3% DM) + WDDGS (3% DM). Trials were conducted as a completely randomized design with a 2x2 factorial (Trial 1) or 2x2+1 treatment arrangement (Trial 2). In trial one, there were no differences ($P > 0.05$) between treatments for final shrunk BW (427.8 ± 29.8 kg) or ADG (1.10 0.02 kg). Similarly, DMI and G:F were not affected ($P > 0.05$) by treatment. In trial 2, no treatments differences ($P > 0.05$) were detected for ADG, DMI, or G:F. Cattle fed CM had heavier hot carcass weights ($P = 0.02$) and a greater dressing percentage (DP) ($P = 0.008$) than those fed CRM diets. The inclusion of WDDGS decreased DP ($P = 0.003$) and increased carcass fat deposition ($P \leq 0.04$). The results indicate that there was no benefit to including WDDGS and that CRM is equal to CM as a protein supplement for performance of feedlot cattle. However, HCW and DP were greater in cattle fed CM relative to those fed CRM.

3.1 Introduction

Due to the increasing need for renewable fuel, the bio-oil and biofuel industry has had a considerable expansion in Canada and Unites States in recent years. As a result, a substantial amount of by-product rich in protein content is available after primary processing. From the same family as canola, carinata is an oilseed crop that grows well in semi- arid regions of Western Canada (Getinet et al. 1996). Being a source of non-food oil used primarily as aviation fuel and growing well in saline soils, carinata does not compete for the same land base as canola. Traditional co-products such as canola meal and wheat distillers dried grains with solubles (WDDGS) have been widely evaluated in terms of feeding value for beef cattle (Nair et al. 2015; He et al. 2013; Walter et al. 2010 and 2012 McKinnon and Walker, 2008 and 2009; Beliveau and McKinnon, 2008 and 2009). Results from these and other sources indicate that canola meal averages 40.1% CP, 27.0 % NDF and 19.5% ADF, while WDDGS averages 39.5% CP, 41.8% NDF and 13.8% ADF (DM basis), respectively (Bell, 1993; Xin and Yu 2013 and 2014; McKinnon, unpublished; NRC, 2016; Canola Council of Canada, 2015; Wheat DDGS Feed Guide, 2013; McKinnon and Walker, 2008). By way of comparison, Xin and Yu (2013) reported that carinata meal is higher in crude protein (48.1 vs. 40.4%) and lower in NDF (18.8 vs. 27.5%) and ADF (11.4 vs. 18.6%) relative to canola meal. Therefore, the value of carinata meal as a protein supplement may be the same or higher than that of canola meal.

There are no published performance data on feedlot cattle fed carinata meal as a protein supplement. However, McKinnon et al. (unpublished), in an initial study reported no differences in ADG, DMI, G: F and carcass quality with backgrounded yearling steers fed carinata meal, canola meal or a 50:50 carinata and canola meal blend at a 10% inclusion level (DM basis). Canola meal and WDDGS in contrast are established protein sources for feedlot cattle rations. For

instance, Nair et al. (2015) investigated feedlot steers fed different sources (*B. napus* and *B. juncea*) and levels (15% and 30% in the backgrounding phase and 10% and 20% DM basis in the finishing phase) of canola meal replacing barley grain. The authors showed that cattle fed canola meal up to 30% (DM basis) during the backgrounding phase had DMI and ADG enhanced. However, feed efficiency (G: F) was improved only in steers fed 30% (DM basis) *B. juncea* variety relative to the control. During the finishing phase, G:F, NE_m and NE_g were affected negatively in steers fed canola meal (20% DM basis) regardless of type. With respect to WDDGS, Beliveau and McKinnon (2008) reported that backgrounding feedlot cattle fed graded levels of WDDGS at 24 and 32% WDDGS (DM basis) showed increased G: F and ADG in comparison to 8 and 16% WDDGS inclusion (DM basis). Relative to the finishing period, there was no effect on performance and carcass characteristics of cattle fed low (6 to 12% DM basis) or high (18 to 23% DM basis) levels of WDDGS. However, Walter et al. (2010) reported a linear decrease and a quadratic increase in days on feed and calculated NE_g of feedlot steers fed WDDGS and corn DDGS up to 40% (DM basis), respectively.

Due to the high level of crude protein and relative low fibre content of carinata meal, further research is required in order to develop and market this co-product in comparison with commonly fed protein supplements in the diets of growing and finishing cattle. The objectives of this research were to compare carinata meal to canola meal as a protein source in diets of growing beef steers and the value of carinata meal to canola meal as a protein supplement when fed alone or in combination with WDDGS in finishing rations of yearling steers.

3.2 Material and Methods

3.2.1Animal Management

3.2.1.1 Trial 1 Backgrounding Performance Data

Trial 1 was a 97-day backgrounding trial that used a total of 360 recently weaned cross-bred calves (shrunk initial BW = 321.8 ± 24.3 kg). All cattle were obtained from commercial sources and shipped to the University of Saskatchewan Beef Cattle Research Unit (Saskatoon, SK, Canada). Upon arrival, cattle from both trials were processed including an ear tag and treated with Bimectin™ Pour-On (Bimedia, Le Sueur, MN), Ultrabac 7/Somubac (Zoetis, Kirkland, QC), Bovi-Shield gold one™ (Zoetis, Kirkland, QC), Liquamycin LA-200 (Zoetis, Kirkland, QC) and Revalor®-G implant (Intervet Inc., Kirkland, QC). All calves were stratified from lightest to heaviest BW (unshrunk BW) and within weight strata, randomly assigned to one of twelve pens (30 calves/pen). Each pen was randomly assigned to one of the four treatments.

Prior to the initiation of the first trial, all cattle were fed a receiving diet, that consisted of 33.2% rolled barley, 29.3% brome grass/alfalfa hay, 32.5% barley silage, and 5.0% supplement (DM basis). Steers were weighed prior to the morning feeding on two consecutive days at the start and end of test to obtain an average start of test weight. Body weights were measured every two weeks before the morning feeding. At the end of the trial, final body weights were measured on two consecutive days with a target end-point shrunk BW of 425 kg.

3.2.1.2 Trial 2 Finishing Performance Data

Trial 2 was a finishing trial, that lasted 125 days with a total of 250 cross-bred steers (shrunk initial BW = 418.7 ± 26.7 kg). Steers were obtained from commercial sources and shipped to the University of Saskatchewan Beef Cattle Research Unit (Saskatoon, SK, Canada). Upon arrival,

steers were processed similarly as the cattle in Trial 1. Steers were randomly assigned to one of twenty-five pens (10 calves/pen). Each pen was randomly assigned to one of five treatments. The receiving diet was composed of 33.3% rolled barley, 29.3% brome grass/alfalfa hay, 32.4% barley silage, and 5.0% supplement (DM basis). Body weights were measured following the same protocol as Trial 1. Final body weights were measured on two consecutive days with a target shrunk BW of 650 kg. The steers were cared for according to guidelines of the Canadian Council on Animal Care (2009).

3.2.2 Dietary Treatments and Feeding Management

3.2.2.1 Trial 1 Backgrounding Performance Data

Trial 1 was designed as a CRD with a 2x2 factorial arrangement of treatments. Dietary treatments included carinata meal or canola meal fed at 7.5 or 15% (DM basis) (Table 3.1). All diets were formulated to meet or exceed energy (1.5 and 0.9 Mcal/kg of NE_m and NE_g, respectively, DM basis) and CP (12.5%, DM basis) requirements of growing cattle, targeting a daily gain of 1.1kg/d (NRC, 2000). Monensin sodium was fed at 33 ppm. Agrisoma Biosciences Inc., Saskatoon, SK, Canada provided the carinata meal, which originated from brown colored seed. The seed was processed (via pressing, solvent extraction, desolventizing and toasting) by Archer Daniels Midland Company, MN, USA. Federated Co-op Ltd, Saskatoon, SK, Canada supplied canola meal (processed via pressing, solvent extraction, desolventizing and toasting). The barley silage (cv. Ranger) was grown at the University of Saskatchewan. Barley grain was purchased from commercial sources. The barley grain was processed to a PI index ranging from 75 to 80%.

Table 3.1. Composition and chemical analysis for the diets fed during backgrounding trial.

	Dietary Treatments			
	CRM 7.5%	CRM 15%	CM 7.5%	CM 15%
Ingredients (%DM)				
Barley grain	33.8	26.3	33.7	26.3
Carinata meal	7.9	15.4	-	-
Canola meal	-	-	8	15.5
Hay	10.1	10.0	10.0	10.0
Barley silage (var. Ranger)	30.2	30.2	30.2	30.2
Barley straw	12.8	12.9	13	12.9
Supplement	5.1	5.1	5.1	5.1
Supplement composition [a]				
Ground Barley	28.0	28.0	28.0	28.0
Wheat Ground	25.0	25.0	25.0	25.0
Prairie Pride Pellets	25.0	25.0	25.0	25.0
Canola Oil	1.5	1.5	1.5	1.5
Limestone	15.2	15.2	15.2	15.2
Mineral, vitamin premix	5.3	5.3	5.3	5.3
Ration Analysis [b]				
DM (%)	51.7 ± 2.10	51.3 ± 2.03	51.3 ± 2.44	51.5 ± 1.92
OM (% DM)	93.1 ± 0.21	92.5 ± 0.25	92.6 ± 0.45	92.6 ± 0.40
CP (% DM)	12.5 ± 0.39	14.1 ± 0.75	12.2 ± 0.31	13.7 ± 0.58
ADF (% DM)	24.2 ± 1.88	25.6 ± 1.36	26.9 ± 1.76	27.1 ± 0.82
NDF (% DM)	37.6 ± 1.27	38.9 ± 0.74	41.2 ± 3.80	40.5 ± 1.28
Ca (%DM)	0.6 ± 0.05	0.6 ± 0.04	0.6 ± 0.06	0.7 ± 0.09
P (% DM)	0.4 ± 0.02	0.5 ± 0.02	0.4 ± 0.04	0.4 ± 0.03
Energy value (Mcal kg^{-1})[c]				
NE_m	1.47 ± 0.03	1.48 ± 0.09	1.50 ± 0.04	1.44 ± 0.03
NE_g	0.89 ± 0.01	0.90 ± 0.10	0.91 ± 0.04	0.86 ± 0.02

Note: CRM =*Brassica carinata; CM*= Brassica napus; Treatments included 7.5% or 15% meal in TMR (DM basis)

[a]Supplement pellet was formulated to supply CP = 10.4%; crude fat = 3.8%, crude fibre = 5.0%, Ca = 7.0%, P = 0.37%, Mg = 0.24%, K = 0.66%, S = 0.14%, and Na = 1.80% of dietary DM, monensin = 662.3 mg /kg, Co = 5.4 mg/kg, Cu = 202.4 mg/kg, I = 18.4 mg/kg, Fe = 111.8 mg/kg, Mn = 554.9 mg/kg, Se = 2.2 mg/kg, Zn = 616.7 mg/kg, vitamin A = 44,450 IU/kg, vitamin D3 = 5,505 IU/kg, vitamin E = 662 IU/kg of supplement

[b]Analysis was conducted by Cumberland Valley Analytical Services (Hagerstown, MD)

[c]Net Energy of Maintenance (NE_m) and Net Energy of Gain (NE_g) based on chemical analysis of feed and calculated according to the equations by Weiss et al. (1992); Mean ± SD.

Feed was offered ad libitum once daily as a total mixed ration (TMR) with the objective to have no more than 5% orts. Bunks were read each morning and the daily feed allotted was based on the residual in the bunk and the amount fed the previous day. Every two weeks throughout the feeding trial prior to the morning feeding, feed bunks were cleaned and orts weighed and recorded. The orts were sampled and analyzed for moisture content. The DM content of the orts was then adjusted against the DM delivered to the bunk over that two-week period. Feed and TMR samples were collected every two weeks to determine DM to adjust ingredient content in the rations. These samples were then pooled by month and treatment for chemical analysis.

3.2.2.2 Trial 2 Finishing Performance Data

Trial 2 was focused on the finishing phase and was designed as 2x2 plus 1 factorial. Dietary treatments included carinata meal; canola meal; WDDGS; carinata meal plus WDDGS or canola meal plus WDDGS (Table 3.2). The basal diet included barley silage, barley grain and supplement (Federated Co-op Ltd) and targeted NCR (2016) nutrient requirements for finishing cattle (i.e. 1.85 and 1.2 ± 0.09 Mcal/kg of NE_m and NE_g, respectively and 13.5% CP, DM basis). Monensin sodium was fed at 33 ppm. Carinata and canola meal, DDGS, barley silage and barley grain were obtained from the same sources as Trial 1. As well, the feeding management protocol was the same as in Trial 1.

3.2.3 Chemical Analysis

In both trials, ingredient and total mixed ration (DM) content were determined by oven drying samples (forage, barley grain, carinata meal, canola meal, WDDGS and orts samples) at 55° C for 72 hours. Samples were ground using a hammer mill through a 1-mm screen (Christie-Norris

Table 3.2. Composition and chemical analysis for the diets fed during finishing trial.

	Dietary Treatments				
	CRM	CM	WDDGS	CRM + WDDGS	CM + WDDGS
Ingredients (% DM)					
Barley grain	75.6	75.8	75.5	75.4	75.6
Carinata meal	5	-	-	2.8	-
Canola meal	-	5.9	-	-	3
WDDGS	-	-	6.2	2.7	3
Barley silage (var. Ranger)	14	12.9	13.8	13.7	13.0
Supplement	5.4	5.4	5.4	5.4	5.4
Supplement composition[a]					
Ground Barley	28.0	28.0	28.0	28.0	28.0
Wheat Ground	25.0	25.0	25.0	25.0	25.0
Prairie Pride Pellets	25.0	25.0	25.0	25.0	25.0
Canola Oil	1.5	1.5	1.5	1.5	1.5
Limestone	15.2	15.2	15.2	15.2	15.2
Mineral, vitamin premix	5.3	5.3	5.3	5.3	5.3
Ration Analysis[b]					
DM (%)	83.5 ± 1.49	83.9 ± 1.31	82.6 ± 4.20	84.1 ± 1.65	84.3 ± 1.44
OM (% DM)	95.0 ± 0.74	95.0 ± 0.53	95.0 ± 0.33	95.1 ± 0.58	94.9 ± 0.60
CP (% DM)	13.9 ± 0.57	13.0 ± 0.59	13.9 ± 0.87	14.0 ± 0.50	13.7 ± 0.81
ADF (% DM)	9.8 ± 1.71	9.7 ± 1.06	8.4 ± 0.63	8.4 ± 0.21	8.3 ± 0.57
NDF (% DM)	21.2 ± 2.94	20.7 ± 1.48	21.4 ± 1.28	21.3 ± 0.69	20.0 ± 1.45
Ca (% DM)	0.7 ± 0.04	0.7 ± 0.06	0.7 ± 0.14	0.7 ± 0.11	0.7 ± 0.06
P (% DM)	0.5 ± 0.03	0.5 ± 0.03	0.5 ± 0.05	0.5 ± 0.03	0.5 ± 0.03
Energy value (Mcal kg^{-1})[c]					
NE_m	1.85 ± 0.03	1.85 ± 0.01	1.85 ± 0.01	1.89 ± 0.02	1.87 ± 0.01
NE_g	1.21 ± 0.03	1.21 ± 0.01	1.21 ± 0.01	1.25 ± 0.01	1.23 ± 0.01

Note: CRM = Carinata meal; CM = Canola meal; WDDGS = Wheat based dried distillers grains with solubles.

[a]Supplement pellet was formulated to supply CP = 10.4%; crude fat = 3.8%, crude fibre = 5.0%, Ca = 7%, P = 0.37%, Mg = 0.24%, K = 0.66%, S = 0.14%, and Na = 1.80% of dietary DM, monensin = 662.3 mg /kg, Co = 5.4 mg/kg, Cu = 202.4 mg/kg, I = 18.4 mg/kg, Fe = 111.8 mg/kg, Mn = 554.9 mg/kg, Se = 2.2 mg/kg, Zn = 616.7 mg/kg, vitamin A = 44,450 IU/kg, vitamin D3 = 5,505 IU/kg, vitamin E = 662 IU/kg of supplement.

[b]Analysis was conducted by Cumberland Valley Analytical Services (Hagerstown, MD).

[c]Net Energy of Maintenance (NE_m) and Net Energy of Gain (NE_g) based on chemical analysis of feed and calculated according to the equations by Weiss et al. (1992); Mean ± SD.

Laboratory Mill, Christie-Norris Ltd., Chelmsford, UK). For concentrate analysis, samples were ground using a Retsch ZM 100 grinder (Haan, Germany) using a 1 mm screen. Protein sources and TMR samples from the backgrounding and finishing trials were analyzed by Cumberland Valley. Analytical Services (CVAS, Hagerstown, MD) for DM by drying at 135° C (AOAC method # 930.15), CP (AOAC method # 948.13), SP by the boratephosphate method (Krishnamoorthy et al. 1982), ADICP (AOAC method # 990.03), NDICP (AOAC method # 990.03), ash (AOAC method # 942.05), ADF (AOAC method # 973.18) and NDF (AOAC method # 2002.04), calcium (AOAC method # 927.02) and phosphorus (AOAC method # 965.17) according to the Association of Official Analytical Chemists (2000). Glucosinolate content of the carinata and canola meal was analyzed by POS BIO-SCIENCES, Saskatoon, Saskatchewan, Canada, according to the Canadian Grain Commission method (Daun and McGregor, 1983).

3.2.4 Carcass traits

At the end of the finishing trial, steers were shipped to the Cargill Meat Solutions (High River, AB). Before being chilled, hot carcass weight was recorded. Carcasses were graded by camera following the guidelines of the Canadian Beef Grading Agency (CBGA 2009). Dressing percentage was calculated by carcass and live weight. Grade fat was calculated by determination of subcutaneous fat estimated perpendicular to the outside surface, within the fourth quarter of the rib-eye at the minimal point of thickness. Grade data included marbling and yield evaluation. Marbling scores included Canada A (Marbling score 300); Canada AA (Marbling score 400); Canada AAA (Marbling score 500) and Canada Prime, (Marbling score 800). The yield estimation was Lean meat yield, %: Canada 1= 59% or greater; Canada 2, 58 to 54%; Canada 3, 53% or less.

3.2.5 Data Calculation and Statistical Analysis

In both trials, average daily gain (ADG) was calculated using the initial shrunk BW less the final shrunk BW averaged by pen and divided by total number of days on trial (NRC, 2016). Feed efficiency (G:F) was calculated using the ratio ADG/DMI. In trial 2, NE_m and NE_g of the diet (Mcal/kg DM) derived from animal performance (BW, ADG and DMI) were calculated according to Zinn et al. (1998). Trial 1 was analyzed with the Mixed Model procedure of SAS (version 9.3; SAS Institute, Inc. Cary, NC) as a completely randomized design with a 2 (carinata meal vs. canola meal) x 2 (7.5 vs. 15%) factorial arrangement of treatments with pen as the experimental unit and treatment as the fixed effect. Significance was declared at $P < 0.05$ and tendencies were declared when $0.05 < P \leq 0.10$. Denominator degrees of freedom were determined using Kenward-Roger option. Trial 2 was first analyzed as a CRD with a pen as experimental unit. Means were separated using Tukey's multi treatment comparison method. Following this, a second model was run, where the WDDGS diet was dropped and the effects of meal type, WDDGS inclusion, and meal type x WDDGS interaction were analyzed as a 2 x 2 factorial. The Univariate procedure of SAS was used to check for normality assumptions. Quality grade data and yield were analyzed using GLIMMIX with a binomial error structure and logit data transformation (SAS, version 9.3, Inc. Cary, NC).

3.3 Results and Discussion

3.3.1 Chemical Composition of Carinata and Canola Meals and Total Mixed Rations

Chemical analysis of the meals used for the Trial 1 and Trial 2 is reported in Table 3.3. In trial 1, carinata meal was slightly higher in CP (43.9 ± 2.55 vs. 39.8 ± 2.55) and somewhat lower in NDF (21.4 ± 1.65 vs. 29.2 ± 0.21) and ADF (11.8 ± 0.85 vs. 20.4 ± 0.85) content than canola meal.

Table 3.3. The chemical profile of carinata meal (CRM), canola meal (CM) and wheat dried distillers's grains with solubles (WDDGS) using in Trial 1 and Trial 2.

	Protein Sources				
	Carinata Meal		Canola Meal		WDDGS
Ingredients	Trial 1	Trial 2	Trial 1	Trial 2	Trial 2
DM (%)	90.0 ± 1.20	92.9 ± 1.16	90.1± 0.86	91.3 ± 0.06	91.9 ± 1.34
OM (% DM)	91.8 ± 1.07	92.1 ± 0.11	92.5 ± 0.42	92.5 ± 0.18	93.6 ± 0.43
CP (% DM)	43.9 ± 2.55	46.9 ± 4.07	39.8 ± 2.55	41.6 ± 0.23	40.1 ± 0.51
SP (% DM)	8.7 ± 1.91	9.7 ± 0.89	7.6 ± 1.34	7.7 ± 1.85	3.7 ± 1.16
SP (%CP)	19.6 ± 3.25	20.7 ± 1.42	18.8 ± 2.26	18.4 ± 4.41	9.3 ± 2.98
ADICP[a] (%DM)	1.6 ± 0.08	1.6 ± 0.11	2.6 ± 0.05	2.6 ± 0.14	4.9 ± 1.94
ADICP (%CP)	3.8 ± 0.42	3.5 ± 0.21	6.7 ± 0.42	6.2 ± 0.35	12.3 ± 4.72
NDICP[b] (% DM)	6.1 ± 0.57	6.1 ± 2.18	4.0 ± 0.30	4.2 ± 0.65	7.0 ± 1.39
NDICP (%CP)	13.9 ± 0.57	12.9 ± 4.11	10.1 ± 0.01	10.0 ± 1.65	17.5 ± 3.47
ADF (%DM)	11.8 ± 0.85	11.8 ± 0.30	20.4 ± 0.85	20.0 ± 1.06	13.2 ± 1.17
NDF (% DM)	21.4 ± 1.65	21.6 ± 0.56	29.2 ± 0.21	28.4 ± 0.67	37.2 ± 1.21
Ca (% DM)	0.6 ± 0.04	0.6 ± 0.06	0.9 ± 0.08	0.9 ± 0.05	0.1 ± 0.02
P (% DM)	1.3 ± 0.11	1.4 ± 0.09	1.2 ± 0.15	1.3 ± 0.06	1.1 ± 0.02
Energy value (Mcal kg^{-1})[c]					
NE_m	1.93 ± 0.29	.	1.47 ± 0.06	1.45 ± 0.02	1.89 ± 0.02
NE_g	1.28 ± 0.25	.	0.88 ± 0.04	0.86 ± 0.02	1.25 ± 0.02

Note: Analysis was conducted by Cumberland Valley Analytical Services (Hagerstown, MD) Carinata meal (n = 7); Canola meal (n = 7); WDDGS (n = 3)

[a]ADICP = Acid detergent insoluble CP

[b]NDICP = Neutral detergent insoluble CP

[c]Net Energy of Maintenance (NE_m) and Net Energy of Gain (NE_g) based on chemical analysis of feed and calculated according to the equations by Weiss et al. (1992); Mean ± SD.

During Trial 2, the carinata meal utilized was higher in CP (46.9 ± 4.07 vs. 41.6 ± 0.23) and lower in NDF (21.6 ± 0.56 vs. 28.4 ± 0.67) and in ADF (11.8 ± 0.30 vs. 20.0 ± 1.06) content relative to canola meal. The WDDGS utilized in Trial 2 was similar (40.1 ± 0.51% vs. 41.6 ± 0.23%) in CP content compared to the canola meal used in the same trial. Relative to carinata meal, Xin and Yu (2013) also reported that that carinata meal had higher CP (48 vs. 40%) and lower in NDF (19 vs. 27%) and ADF (11 vs. 18%) than canola meal. Similar results were reported by McKinnon et al. (unpublished).

The glucosinolate content of the carinata meal was 31.41 ± 1.34 μmol/g and 34.9 ± 5.46 μmol/g for Trial 1 and Trial 2, respectively. These values are higher than the average value of 7.5 μmol/g reported by Newkirk et al. (2003a) in the review of the availability and content of amino acids in toasted and non- toasted canola meals. They are; however, considerably lower (128 μmol/g) than that of the carinata meal used by McKinnon et al. (unpublished) in a backgrounding trial to evaluate carinata meal as a protein supplement for yearling steers.

The lower glucosinolate content of the carinata meal used in the present trial is likely due to the method of processing the seed or improvements in breeding carinata. In the trial by McKinnon et al. (unpublished), the seed was cold pressed without heat while in the present trial seed was pressed, solvent extracted and then processed through a desolventizer and toaster. Recent innovations during processing include treating the meal during the crushing process with an exogenous myrosinase, which is an enzyme that converts allyl glucosinolate to a volatile isothiocyanate. This is an effective method to decrease the glucosinolate of the meal (Agrisoma Biosciences Inc. 2015). Since the volatile isothiocyanate from the treated meal fraction is removed under conditions of mild heat (25°C to 90 °C) and negative pressure, the protein content

of the meal is preserved (Agrisoma Biosciences Inc. 2015). In addition to the processing efforts to reduce glucosinolates, there have been improvements in breeding carinata that have been implemented to develop low glucosinolate seed lines (Getinet et al. 1997; Márquez-Lema et al. 2008). These authors suggested that low glucosinolate *B.* carinata plants could be selected from *B.* juncea lines through genetic crosses. These developments suggested that carinata meal developed either through plant breeding or processing with low anti- nutritional compounds as per the guidelines for canola meal, will exhibit improved palatability and consequently feed intake of cattle while being safe from an animal health perspective.

The chemical analysis of the diets used in Trial 1 are reported in Table 3.1. The data, although not statistically analyzed, shows that when included at similar inclusion levels, carinata meal containing diets were slightly higher in CP (12.5 ± 0.39 and 14.1 ± 0.75 vs. 12.2 ± 0.31 and 13.7 ± 0.58) and lower in neutral (37.6 ± 1.27 and 38.9 ± 0.74 vs. 41.2 ± 3.80 and 40.5 ± 1.28) and acid (24.2 ± 1.88 and 25.6 ± 1.36 vs. 26.9 ± 1.76 and 27.1 ± 0.82) detergent fiber in comparison with diets containing canola meal as a protein supplement. Dietary NE_m (1.5 ± 0.05 Mcal/kg) and NE_g (0.9 ± 0.04 Mcal/kg) values were similar across treatments. Calcium and phosphorus were also not affected by treatment, however calcium was higher in the 15% meal diets relative to 7.5% meal diets (Table 3.3).

Table 3.2 gives the chemical analysis of the diets used in Trial 2 for the finishing cattle. These diets were formulated to be isonitrogenous (13.5% CP); however, as in Trial 1 diets containing carinata meal were slightly higher in CP (13.9% ± 0.57 and 14.0% ± 0.50 vs. 13.0% ± 0.59 and 13.7% ± 0.81) relative to diets with canola meal as a protein supplement. However, the carinata meal diet was similar in CP to the WDDGS diet (13.9% ± 0.57 vs. 13.9% ± 0.87). Acid (8.9% ± 0.76) and neutral (20.9% ± 0.58) detergent fiber as well as calcium (0.7% ± 0.08) and

phosphorus (0.5% ± 0.03) levels were similar across dietary treatments. As these diets were formulated to be isocaloric as such NE_m (1.8 ± 0.05 Mcal/kg) and NE_g (1.2 ± 0.04 Mcal/kg) values were similar between treatments.

3.3.2 Animal Performance

3.3.2.1 Trial 1 Backgrounding Performance

Animal performance results from the Trial 1 are given in Table 3.4. There were no differences ($P > 0.05$) in initial shrunk body weight (321.8 ± 24.27 kg) or final shrunk body weight (427.8 ± 29.76 kg). As a result, ADG (1.10 ± 0.02 kg) was not different ($P > 0.05$) among treatments. Similarly, DMI (7.7 ± 0.24 kg/d) and G:F (0.14 ± 0.01) were not affected ($P > 0.05$) by treatment.

These results demonstrate that carinata meal when fed at 7.5 or 15% of the diet DM (basis) is equivalent to canola meal as a protein supplement for growing cattle. There are no published data relative to carinata meal as a protein supplement for growing cattle. McKinnon et al. (unpublished) supplemented yearling steers with 10% (DM basis) carinata meal or canola meal or with a 50:50 carinata and canola meal blend. The carinata meal used was cold pressed and had a glucosinolate content of 128 μmol/g. The results showed that in the final 42 days of the trial, cattle fed carinata meal had a lower DMI and ADG relative to those fed canola meal and a blend of carinata and canola meal. As a result, NE_m and NE_g content of the carinata meal diet as calculated from animal performance was lower relative to the other two treatments. Performance was not affected by treatment over the remaining 36 days of the trial. These authors speculated that starting cattle on high glucosinolate, carinata meal based diets resulted in palatability issues and thus reduced performance in the initial phase of the trial and that performance issues

Table 3.4. The performance of weaned steer calves fed carinata or canola meal at one of two inclusion levels (7.5 or 15%) during Trial 1.

	Meal							
	Carinata Meal		Canola Meal			*P*-value		
	Level (DM basis)		Level (DM basis)					
Item	7.5%	15%	7.5%	15%	SEM	Meal	Level	Meal × Level
Initial shrunk BW[a](kg)	321.9	321.8	321.7	321.9	0.29	0.86	0.94	0.59
Final shrunk BW[a] (kg)	426.6	428.1	427.0	429.8	3.56	0.78	0.56	0.85
ADG (kg d^{-1})	1.08	1.10	1.09	1.12	0.037	0.73	0.55	0.86
DMI (kg d^{-1})	7.35	7.61	7.91	7.76	0.258	0.21	0.85	0.45
G:F[b]	0.15	0.14	0.14	0.14	0.003	0.16	0.71	0.27
Energy value (Mcal kg^{-1})[c]								
NE_m	1.75	1.71	1.65	1.70	0.032	0.11	0.90	0.21
NE_g	1.13	1.09	1.04	1.08	0.028	0.11	0.90	0.22

Note: CRM =*Brassica carinata;* CM= *Brassica* napus; Treatments included 7.5% or 15% meal in TMR (DM basis)

[a]Shrunken BW was calculated as 96% of live weight (NRC, 1996). The experimental unit was pen (n = 3).

[b]G:F was calculated as ADG/DMI.

[c]Net energy for maintenance (NE_m) and gain (NE_g) was calculated based on performance (Zinn and Shen, 1998; Zinn et al. 2002)

disappeared as the animals adapted to the diet. In the present study, there were no performance disadvantages caused by high glucosinolate levels in the diets as the carinata meal had markedly lower levels of these goitrogenic compounds than McKinnon et al (unpublished) study. As discussed above, the lower glucosinolate content was likely due to the fact that the meal was processed via by desolventizing and toasting after being pressed and solvent extracted (Agrisoma Biosciences Inc. 2015).

Similar performance responses to the present trial have been observed when other high protein by-product feeds have been fed to beef cattle as a protein source. For instance, McKinnon and Walker (2009) reported no differences between treatments in DMI, ADG and G:F of growing cattle when fed a backgrounding diet containing 10% (DM basis) canola meal, or mustard presscake from biodiesel production. Daily gains (1.3 kg/d) and DMI (9.3 kg/d) for cattle fed 10% canola meal were higher than what was observed in the current trial; however, the G:F ratio was similar (0.14) to that in the current trial. Beliveau and McKinnon (2008) reported a cubic improvement in ADG when WDDGS was included in backgrounding diets as a replacement for canola meal and barley. These authors reported similar backgrounding ADG and G:F values as the current study for their control diet which was based on canola meal as a protein supplement. Adding 8% WDDGS decreased ADG and G:F, while higher inclusion levels tended to improve performance.

There have been a number of studies where canola meal has been fed as both a protein and energy source. He et al. (2013) fed canola meal at 20 or 40% (DM basis) from *B. napus* or *B. juncea* in backgroundig diets and reported no treatment effects on DMI, ADG and G:F, regardless of meal level and type. However, Nair et al. (2015) observed an improvement in DMI and ADG for backgrounding cattle fed canola meal at 15 or 30% (DM basis) from *B. napus* or *B. juncea* in

comparison with those fed a urea-based control diet. The authors attributed this result to an improvement in rumen fermentation parameters due to enhanced energy status of cattle supplemented with high protein by-products such as a canola meal. Relative to published studies with canola meal and other byproduct protein sources, the results of the current study indicate that carinata meal fed at 7.5% or 15% (DM basis) in traditional backgrounding diets is equal to canola meal as a protein supplement for growing cattle. There were no benefits to feeding higher levels (i.e. 15%) of either meal.

3.3.2.2 Trial 2 Finishing Performance

Animal performance results from Trial 2 are given in Table 3.5. Regardless of the statistical model used, there was no effect ($P > 0.05$) of treatment on initial (418.7 ± 26.7 kg) and final (649.8 ± 44.1 kg) shrunk BW, ADG (1.85 ± 0.05 kg), DMI (11.92 ± 0.28 kg/d), G:F (0.16 ±0.01), NE_m (1.92 ± 0.02) or NE_g (1.28 ± 0.02 kg) content. No meal type by WDDGS interaction was observed ($P > 0.05$).

Carinata meal has not been previously evaluated as a protein supplement in finishing diets for beef cattle. However conventional high protein by-products such as canola meal, wheat and corn DDGS have been well studied. Nair et al. (2015) reported no effects ($P > 0.05$) of feeding 10% versus 20% canola meal on the performance of finishing steers. In this study, cattle fed a urea-based control diet and those fed 10% canola meal had DMI (11.11 ± 0.29 kg/d) and ADG (1.62 ± 0.02 kg/d) that were slight lower than what was observed in the present study with carinata meal and canola meal diets. G:F ratios (0.146 ± 0.03 kg/d) were similar to the current study. Damiran and McKinnon (submitted) fed a canola meal based finishing ration formulated to similar CP levels as in the current study and also reported values for ADG (1.72 ± 0.08 kg/d),

Table 3.5. Effects of feeding carinata or canola meal with or without wheat dried distiller grains with solubles on finishing performance of feedlot steers in Trial 2.

	Dietary Treatments						*P*-value			
Item	CRM	CM	WDDGS	CRM + WDDGS	CM + WDDGS	SEM	Trt	Meal Type	WDDGS	Meal Type x WDDGS
Initial shrunk BW[a] (kg)	419.1	418.3	418.1	419.1	419	0.61	0.66	0.56	0.53	0.46
Final shrunk BW[a] (kg)	640.8	650.4	647.7	651.9	658.1	5.09	0.23	0.17	0.11	0.76
ADG (kg d^{-1})	1.77	1.86	1.84	1.86	1.91	0.038	0.19	0.13	0.11	0.69
DMI (kg d^{-1})	11.7	12.0	11.6	12.0	12.3	0.221	0.23	0.25	0.26	0.82
G:F[b]	0.15	0.15	0.16	0.16	0.16	0.003	0.59	0.51	0.42	0.75
Energy value (Mcal kg^{-1})[c]										
NE_m	1.9	1.91	1.96	1.92	1.93	0.027	0.68	0.62	0.53	0.91
NE_g	1.25	1.27	1.31	1.27	1.28	0.025	0.74	0.59	0.51	0.87

Note: Backgrounding diet: CRM = Carinata meal; CM = Canola meal; WDDGS = Wheat based dried distillers grains with solubles

[a]Shrunken body weight calculated as 96% of liveweight (National Research Council, 2001)

[b]G:F was calculated as ADG/DMI.

[c]Net energy for maintenance (NE_m) and gain (NE_g) was calculated based on performance (Zinn and Shen, 1998; Zinn et al. 2002)

DMI (11.3 ± 0.29 kg/d) and G:F ratio (0.15 ± 0.01 kg/d) similar to what was observed in the present trial. Supplementing canola meal or WDDGS at 10 or 20% (DM basis) of the diet did not improve performance. In contrast, Nair et al. (2015) found that as canola meal levels increased to 20% in the diet of finishing cattle G:F, NE_m or NE_g values decreased. Similarly, Beliveau and McKinnon (2008) reported finishing gains of 1.8 to 1.9 kg/d and G:F values of 0.16 to 0.17 in diets supplemented with canola meal or WDDGS. Values similar to those observed in the present study. As in Trial 1 with backgrounding cattle, the results of the current trial and comparable published results indicate that carinata meal is an excellent protein supplement for finishing cattle with performance results similar to that seen with canola meal and other common protein supplements.

3.3.3 Carcass Traits

Hot carcass weight, grade fat, *longissimus dorsi* area, marbling score, carcass quality grade, and yield grade were not affected by dietary treatment ($P > 0.05$) (Table3.6). Dressing percentage was higher in animals fed canola meal than those fed carinata meal and WDDGS ($P < 0.01$), but was not different among other treatments.

When the data were analyzed as a 2x2 factorial evaluating meal type, WDDGS inclusion and the meal type x WDDGS interaction, cattle fed canola meal produced heavier ($P = 0.02$) HCW compared to those fed carinata meal diets ($P = 0.02$; 389.4 ± 0.28 vs. 381.4 ± 1.91 kg). As a result, dressing percentage was higher ($P = 0.008$) for cattle fed canola meal compared to those fed carinata meal (59.5 ± 0.42 vs. 59.0 ± 0.42%). Dressing percentage was also reduced ($P = 0.003$) when WDDGS was included in the diets (59.5 ± 0.35 vs. 58.9 ± 0.35%). The inclusion of WDDGS also increased ($P = 0.05$; 11.4 ± 0.64 vs. 13.1 ± 0.07%) grade fat, marbling score ($P = 0.05$; 398.3 ± 3.39 vs. 433.5 ± 2.33%) and the % of carcasses grading Canada YG 3 ($P = 0.04$; 13.6 ± 3.54 vs. 21.3 ± 4.31%).

Table 3.6. Effects of carinata or canola meal with or without wheat dried distiller grains with solubles on carcass characteristics of feedlot steers.

Item	Dietary Treatments					SEM	*P*-value			
	CRM	CM	WDDGS	CRM + WDDGS	CM + WDDGS		Trt	Meal Type	WDDGS	Meal Type x WDDGS
HCW, kg	380.1	389.2	383.2	382.8	389.6	2.61	0.07	0.02	0.59	0.67
Dressing percentage, %	59.3[ab]	59.8[a]	59.2[ab]	58.7[b]	59.2[ab]	0.17	<0.01	<0.01	<0.01	0.92
Grade fat[a], mm	10.9	11.8	11.1	13.1	13.0	0.76	0.17	0.61	0.05	0.50
Longissimus dorsi area, cm×cm	86.1	86.3	86.1	86.4	86.9	3.03	1.00	0.90	0.89	0.97
Marbling score	395.9	400.7	409.4	435.1	431.8	16.55	0.35	0.96	0.05	0.81
QG (%)[b]										
Canada B4 (dark)	0	0	0	0	2.2	0.99	0.43	0.33	0.33	0.33
Canada AA	37.8	32.2	24.4	24.4	20	7.68	0.51	0.56	0.15	0.95
Canada AAA	62.2	67.8	75.6	75.6	77.8	7.45	0.56	0.64	0.17	0.84
YG[c]										
Y1	44.4	36.1	48.9	31.1	27.2	6.79	0.17	0.38	0.12	0.75
Y2	44.4	47.8	33.3	44.4	54.4	4.84	0.08	0.18	0.50	0.50
Y3	11.1	16.1	17.8	24.4	18.3	4.58	0.39	0.88	0.04	0.13

Note: Finishing diet: CRM = Carinata meal, CM = Canola meal, WDDGS = Wheat based dried distillers grains with solubles. Means without a common lower case letter differ ($P < 0.05$)

[a]Grade fat is a measure of subcutaneous fat assessed perpendicular to the outside surface, within the fourth quarter of the rib-eye at the minimum point of thickness.

[b]QG: B4, No quality grade; Canada A, Marbling score 300; Canada AA, Marbling score 400; Canada AAA, Marbling score 500; Canada Prime, Marbling score 800 (Canadian Beef Grading Agency, 2009).

[c]YG: Lean meat yield, %: Canada 1 = 59% to more; Canada 2, 58 to 54%; Canada 3, 53% or less.

Walter et al. (2010) in contrast to the findings of the current study, reported increased dressing percentage of finishing cattle fed WDDGS. However, these authors fed much higher levels (i.e. 40%) of WDDGS than in the current study. The reason for the increased carcass fat particularly when cattle were fed WDDGS is unclear. Beliveau and McKinnon (2008) reported no effect ($P > 0.05$) on dressing percentage, yield grade, or carcass marbling score of feedlot cattle fed graded levels of WDDGS in comparison with a barley based control ration. Gibb et al. (2008) also reported higher levels of carcass grade fat when WDDGS was fed, similar to the current study. However, relative to the current study, these authors fed much higher levels of WDDGS (i.e. 20 to 60% of the diet DM). In the current study, dietary NE_m and NE_g values as calculated from animal performance (Table 3.6) were not influenced by the relative low levels of WDDGS inclusion. As such it is not clear why carcass fatness increased. The results do indicate; however, that relative to canola meal and WDDGS, carinata meal does not negatively influence carcass quality when fed at levels in the current trial.

3.5 Conclusion

The results of this study suggest that carinata meal is equal to canola meal as a protein supplement for backgounding feedlot cattle. The inclusion of WDDGS did not affect animal performance in the finishing trial. Dressing percentage and HCW were greater in cattle fed canola meal relative to those fed carinata meal. The addition of WDDGS did not improve dressing percentage. However, cattle fed diets with WDDGS presented higher grade fat deposition, marbling score and yield grade. The results of these two trials indicate that cattle fed carinata meal will exhibit similar performance to those fed canola meal when fed up to 15% of the diet DM. However, carcass quality, as evident from reduced dressing percentage and HCW was negatively affected.

4.0 COMPARISON OF CARINATA MEAL AND CANOLA MEAL WITH OR WITHOUT WHEAT DRIED DISTILLER'S GRAINS WITH SOLUBLES ON RUMEN FERMENTATION, OMASAL FLOW, MICROBIAL PROTEIN SYNTHESIS AND TOTAL TRACT DIGESTIBILITY CHARACTERISTICS.

Abstract

This study evaluated carinata **(CRM)** versus canola meal **(CM)** fed alone or in combination with wheat-dried distillers' grains with solubles **(WDDGS)** as a protein supplement for beef cattle. The trial was designed as a 4 × 4 Latin square with 4 ruminally-cannulated heifers (386 ± 27.95 kg; mean ± SD) fed a barley-based backgrounding (BK) diet with CRM (9.2% DM); CM (10.0% DM); CRM (5.0% DM) + WDDGS (5.3 DM); or CM (5.0% DM) + WDDGS (5.3 DM) as protein sources. Ruminal and omasal samples were collected every 9 h for 3 d. Fecal output was collected every 2 h for 5 days. Omasal digesta flow and nutrient digestibility were measured with the triple marker technique using chromium-EDTA, ytterbium chloride, and indigestible NDF. Microbial protein synthesis was determined using ammonium sulphate labelled with ^{15}N as a marker. Ruminal pH, ammonia, acetate, propionate and butyrate concentrations were not affected ($P > 0.05$) by treatment. No treatment differences were detected for omasal nutrient flow or apparent digestion of DM, OM or NDF, as well as for true ruminal OM digestion. Apparent digestion of N tended ($P = 0.09$) to be greater for CRM and CM diets relative to WDDGS diets (-10.0 ± 2.73 vs. 13.9 ± 14.81 g d^{-1}). The inclusion of WDDGS increased ($P = 0.04$) N truly digested in the rumen (154.5 ± 0.16 vs. 177.9 ± 0.55 g d^{-1}), and decreased (228.0 ± 2.45 vs. 205.6 ± 20.07 g d^{-1}) ruminal non-ammonia nitrogen (NAN) flow. No treatment differences ($P > 0.05$) were noted in total bacterial NAN flow or in microbial efficiency. Total tract nutrient digestibility was not ($P > 0.05$) affected by treatment. These results indicate that CRM, relative to CM, does not affect rumen

fermentation, nutrient utilization and microbial protein synthesis with no benefit to adding WDDGS as a rumen undegradable protein source.

4.1 Introduction

There has been an increase in the availability of by-product feeds rich in protein and energy content that are derived from the biofuel or bio-diesel industry in North America. As result, some by-products such as canola meal and wheat-dried distiller's grains with solubles (WDDGS) are extensively used as protein and energy sources for beef (Gozho et al. 2008; McKinnon et al. 1991; Petit et al. 1994; He et al. 2013; Nair et al. 2015) and dairy cattle (Hickling, 2007; Mulrooney et al. 2009). *Brassica carinata* or *Ethiopia mustard* is a high protein, low fibre oilseed plant from the *Brassica* family (Getinet et al. 1996). Due to the fact that carinata generates industrial oil used primarily as bio-fuel for the aviation industry and the fact that it grows well in saline soils; it does not compete for the same land base as canola. In addition, since it grows well in semi- arid regions, *Brassica* carinata has the potential to be an economically viable crop in the dry areas of western Canada and the northern plains of the United States. Consequently, the protein value of *Brassica* carinata meal for beef cattle needs to be established.

Based on chemical composition, it has been reported that carinata meal is higher in crude protein and lower in neutral and acid detergent fiber content in comparison with canola meal (Xin and Yu 2013, McKinnon et al. unpublished). By way of comparison, WDDGS is an ethanol by-product with a relatively high level of crude protein and fibre. WDDGS is extensively used as a protein and energy source for backgounding and finishing cattle (McKinnon and Walker 2008; Beliveau and McKinnon 2008 & 2009; Walter et al. 2010). While carinata or canola meal are relatively good sources of rumen degradable protein (RDP) Xin and Yu (2014) which is the

principal nitrogen source for microbial protein synthesis Chibisa et al. (2012), WDDGS has been reported to be high in rumen undegradable protein (RUP) (Nuez-Ortin and Yu 2009; Boila and Ingalls, 1994). Microbial protein, RUP and endogenous protein comprise metabolizable protein, which once absorbed from the small intestine, supplies the animal's AA requirements for maintenance and production (Chibisa et al. 2012). Therefore, it is possible that a blend of protein supplements such as carinata meal or canola meal with WDDGS will improve rumen MCP synthesis and flow of MP to the small intestine.

No published reports have been carried out comparing carinata meal or canola meal with or without WDDGS on ruminal fermentation, total tract digestibility characteristics, microbial protein synthesis and omasal N flow in beef cattle. Due to the advantageous economic and chemical aspects of carinata meal in comparison with conventional protein sources for beef cattle such as canola meal, the protein value of carinata meal for feedlot cattle needs to be explored. The objectives of the present study were to measure the effects of carinata meal relative to canola meal when fed alone or in combination with a source of rumen undegradable protein (WDDGS) on rumen fermentation, total tract digestibility characteristics, microbial protein synthesis and omasal nutrient flow of beef heifers fed backgrounding diets.

4.2 Materials and Methods

4.2.1 Animal and Housing and Experimental Design

Four Hereford heifers (386 ± 27.95 kg) were obtained from commercial sources and housed in 9 m^2 pens equipped with rubber mats on the floor and individual water bowls and feeders at the University of Saskatchewan Metabolism Unit (Saskatoon, SK, Canada). All heifers were cared for as per the guidelines of the Canadian Council on Animal Care (CCAC 2009). Three months before

the trial started, the heifers were ruminally cannulated and outfitted with 9-cm soft rubber cannulas (Barr Diamond, Parma, ID).

Each heifer was assigned randomly to 1 of 4 treatments using a 4x4 Latin square design. Prior to the start of the trial, the cattle were maintained on a backgrounding diet consisting of 70% forage and 30% concentrate. The duration of the trial was approximately 124 days and consisted of four 31 d periods. The first 7 days of each period were used for diet adaptation; with voluntary intake measured from days 8 to 13. Days 13 through 22 were used for marker infusion and omasal and rumen fluid collection. Days 26-31 were used for total fecal and urine collection. From day 23 throughout the rest of the period, the cattle were fed at 95% of voluntary intake to ensure consumption of all feed. Body weights were taken on days 1, 8, 13 and 31 in order to calculate DM intake as a percentage of body weight.

4.2.2 Treatments and Dietary Composition

Dietary treatments involved comparison of carinata meal versus canola meal as the sole protein supplement or when fed in combination with WDDGS. During the trial the heifers were fed *ad libitum* in 2 equal portions at 0800 and 1600h each day. Orts were removed, weighed and recorded daily before the morning feeding. Basal feed ingredients included barley silage, barley grain and a mineral-vitamin supplement (Federated Co-op Ltd. Saskatoon, SK, Canada) that included ground barley (58.1%), prairie pride pellets (10%), limestone (23.5%), tallow (1.0%) mineral-vitamin premix (7.4%). Monensin sodium was included in the total mixed diet at 33 mg kg^{-1} (DM basis). Diets were formulated to achieve CP, NE_m and NE_g levels that targeted ~1.1 kg daily gain (NRC, 2000).

4.2.3 Data Analysis

In order to maintain/adjust the forage to concentrate ratio, samples of barley silage (cv. Ranger) grown at the University of Saskatchewan farm were taken every week. Barley grain purchased from commercial sources was dry rolled at the Beef Cattle Research and Teaching Unit of the University of Saskatchewan before transporting to the Livestock Research Facility. Canola meal was supplied by Federated Co-op Ltd, Saskatoon, SK, Canada, while carinata meal (desolventized and toasted via Archer Daniels Midland Company, MN, USA) was provided by Agrisoma Biosciences Inc., Saskatoon, SK, Canada. Daily samples of feed and orts were recorded and subsampled during the voluntary intake and total tract collection period. Samples were dried at 55˚C for 72 hours and ground by a hammer mill through a 1-mm screen (Christy & Norris 8" Lab mill, Christy Turner Ltd. Chelmsford, UK). For concentrate analysis, samples were ground using a Retsch ZM 100 grinder (Haan, Germany) using a 1mm screen, and stored for subsequent chemical analysis.

4.2.4 Marker and Omasal Sampling Technique

Digesta flow and nutrient digestibility were measured by the triple marker technique according to France et al. (1986). Markers for the fluid (FP), small (SP), and large particle (LP) phases were Cr-EDTA, $YbCl_3$ and iNDF, respectively (Uden et al. 1980; Siddons et al. 1985**).** To quantify ruminal microbial protein production, N-15 labelled ammonium sulphate ($^{15}NH_42SO_4$; 10 atom percent excess N^{15}; Cambridge Isotope Laboratories) was used as a microbial marker (Reynal et al. 2005). On day 13, just before marker solution infusion, a 450-mL omasal digesta sample was collected and stored at -20°C in order to measure ^{15}N (^{15}NB), Cr-EDTA and $YbCl_3$ natural abundance. Priming doses equal to one-half of the daily dose of $YbCl_3$, $(^{15}NH_4)_2SO_4$, and Cr-

EDTA were administered via the ruminal cannula. Marker solutions were continuously introduced into the rumen using a peristaltic pump starting on day d-13 for a period of 10-d (7d for rumen adaptation and 3d for digesta sampling) at a constant rate of 1L/ d, providing 3.35g of $YbCl_3$ (Brito et al. 2006), 0.22g of ^{15}N (Brito et al. 2006) and 2.27g of Cr-EDTA (Binnerts et al. 1968).

The omasal sampling technique (Huhtanen et al. 1997) was utilized to collect digesta flow to the omasum for measurement of omasal digesta phases and microbial protein production. To obtain a representative 24-hour feeding period, samples were taken at 9-h intervals over 3 consecutive days with 2-hour incremental change every sampling day. Briefly, omasal digesta was collected from each cow at 0800 and 1700 h on d 20; 0200, 1100, and 2000 h on d 21; 0500, 1400 and 2300 h on d 22. A 525-mL sample of omasal digesta was then divided into 100-, 125- and 300-mL subsamples. To provide an 800 mL and 2.4-L composite sample, the 100 and 300mL subsamples were pooled by heifer over the sampling period and stored at -20°C until analysis. The 800-mL composite sample of omasal digesta was used as a spare. The 2-L composite sample was used to measure large particle (LPP), small particle (SPP), and fluid (FPP) omasal digesta phases as described by Reynal et al. (2005). In order to isolate fluid-associated (FAB) and particle-associated (PAB) bacteria (Brito et al. 2009), immediately after collection the 125-mL subsamples were put in an ice-bath and combined over 2 consecutive sampling times (i.e. 0800 and 1700 h on day 20) to produce a 250-mL composite sample, which was filtered and centrifuged as described by Reynal et al. (2005).

4.2.5 Rumen Fermentation

4.2.5.1 Rumen Fluid Collection

Ruminal fluid was collected over 24 hours at 8-h intervals over 3 d, starting on day 20 at 0800 h as was done with omasal samples. Approximately 250-mL of ruminal liquid from four different locations of the rumen (ventral, anterior, posterior, and rumen mat) were collected. Next, it was strained through two layers of cheesecloth and solids discarded. The pH was measured in duplicate and recorded, using a portable pH meter (model 265A, Orion Research Inc., Beverly, MA). Two 10-mL filtrate samples were sub-sampled into 15-mL centrifuge tubes (Fisher Scientific, Waltham, MA). To one of these samples, 2-mL of 25% metaphosphoric acid was added for VFA analysis, to the second tube 2-mL of 1% sulphuric acid was added for ammonia analysis. All samples were stored at -20^0C.

4.2.5.2 Volatile Fatty Acid and Ammonia Analysis

Samples for VFA analysis were thawed overnight at 4°C. Samples were then thoroughly mixed and centrifuged at 12,000 g for 10 min at 4°C using a Beckman Centrifuge (Model Avanti J-E; Palo Alto, CA). Following this step, 1.0-mL of sample was placed in microcentrifuge tubes (VWR ™ 1.5 mL microcentrifuge tube with snap cap, Radnor, PA). Samples were then centrifuged at 16,000 g for 10 min at 4°C using a microcentrifuge (Beckman Coulter ™, Brea, CA). An internal standard containing 300 μL isocaproic acid, 20-mL of 25% metaphosphoric acid and double distilled water was mixed with 1-mL of the supernatant sample in a GC vial (Agilent Technologies™, Santa Clara, CA) to measure the concentration of VFA by comparison of peak areas using an Agilent 6890 series Gas chromatography system (Agilent Technologies ™, Santa Clara, CA) equipped with an Agilent 7683 series 5 μL injector, Zebron ZB-FFAP high

performance GC capillary column (30 m x 320 μm x 0.25 μm, Phenomenex, Torrance, CA) and an Agilent split focus liner (Agilent Technologies™, Santa Clara, CA). To prevent volatilization, samples were prepared daily and kept at 4°C until analysis. Acetic, propionic, butyric, isobutyric, valeric, isovaleric, caproic and isocaproic acids were used as a mixed standard to build a calibration curve.

Samples of ruminal fluid for ammonia analysis were thawed overnight at 4°C, vortexed and centrifuged at 12,000 g for 10 min at 4°C using a Beckman Centrifuge (Model Avanti J-E; Palo Alto, CA). Following this, 1.0-mL of sample was placed in microcentrifuge tubes (VWR ™ 1.5-mL microcentrifuge tube with snap cap, Radnor, PA) and centrifuged at 16,000 g for 10 min at 4°C using a microcentrifuge (Beckman Coulter ™, Brea, CA). The phenol-hypochlorite method of Broderick and Kang (1980) was used to determine ammonia concentration of ruminal fluid.

4.2.6 Total Tract Collection

Total tract collection of urine and feces was conducted for 5 days (d 26 to 31) in each period. One day before collection, indwelling bladder catheters (Bardex Foley catheter, 8.7 mm, 75-mL ribbed balloon, medium length round tip, C R Bard Inc., Covington GA, 30014, USA) were inserted in the heifers and attached to Nalgene plastic tubes. Urine was collected into sealed 20-L Nalgene plastic vesicles. At 0800 h starting on day 26, total daily fecal output was collected from the floor every 2 h from 0600 to 2200 h and every 4 h from 2200 to 0600 h, and stored in plastic containers with lids for each 24 h period. The total fecal output was weighed daily from d 27 to 31 at 0800 h. An amount equating to 5% of the daily total fecal output was taken and placed into pre-weighed aluminium trays and stored at -20°C. It was then dried at 55°C for 120 h and ground to pass

through a 1-mm screen (Retsch ZM 100 grinder Haan, Germany), and stored in plastic vials until analysis.

4.2.7 Sample Analysis

Individual feed ingredients, refusals and fecal samples were analyzed for DM by drying at 135^0 C (AOAC method # 930.15), CP (AOAC method # 948.13), SP by the boratephosphate method (Krishnamoorthy et al. 1982), AIDCP (AOAC method # 990.03), NDICP (AOAC method # 990.03), ash (AOAC method # 942.05), ADF (AOAC method # 973.18) and NDF treated with amylase and with the addition of sodium sulphite (AOAC method # 2002.04). Calcium and P was determined using the dry ashing procedure (methods # 927.02 and # 965.17; respectively). All analysis were carried out by Cumberland Valley Analytical Services (CVAS, Hagerstown, MD) according to the Association of Official Analytical Chemists (2000). A Parr 1281 bomb calorimeter (Parr Instrument Company, Moline, IL) was utilized to determine gross energy of feed ingredients, refusals and feces.

Omasal samples of ^{15}N background and bacterial pellets were composited by animal and by period before being freeze-dried, and ground with a mortar and pestle and pulverized with a ball mill. They were then analyzed for NAN and ^{15}N. As a described by Reynal et al. (2005), the 2.4L of composite omasal digesta were thawed at room temperature, filtered and centrifuged at 1000 g for 5 minutes at 5°C before being divided into fluid, large and small particle phases. These were freeze- dried and ground through a 1-mm screen using a Christy-Norris mill. According to Vicente et al. (2004), 1-g sample of each omasal digesta phase was combusted at 550°C for 8 h in a muffle furnace (AOAC, 1990) and digested with nitric acid to determine the concentration of Yb and Cr. Atomic emission spectroscopy (Varian Spectra 220, Varian, Mulgrave, Australia) and

atomic absorption spectrophotometry (Perkin Elmer 2300, Perkin-Elmer Corp., Norwalk, CT) was used to measure Yb and Cr, of omasal and infusion samples, respectively. Concentration of indigestible NDF was measured by using ruminal in situ incubation according to Reynal et al. (2005). This involved taking 1.5, 3.0 and 3.5g samples of LP, TMR, and SP and placing into 5x10-cm nylon mesh bags (6-μm pore size; part no. 03-6/5, Sefar America Inc., Depew, NY) and incubating in the rumens of 3 cannulated heifers for 12 days.

Following the procedure of France and Siddons (1986), omasal true digesta (OTD) was physically reconstituted through the concentrations of Cr, Yb and iNDF in the FPP, SPP and LPP. Particle Phase (PP) was reconstituted from LPP and SPP. Reconstituted OTD was then analyzed for DM by drying at 135^0 C (AOAC method # 930.15), CP (AOAC method # 948.13), ash (AOAC method # 942.05), ADF (AOAC method # 973.18) and NDF treated with amylase and with the addition of sodium sulphite (AOAC method # 2002.04) in order to establish the flow of nutrients to the omasum. Following Broderick and Kang (1980), NH_3-N was measured in OTD through the phenol-hypochlorite method. Next, 0.5 g of OTD sample was thoroughly mixed with 10 mL of 0.07 *M* sodium citrate (pH 2.2) before being dried in a forced-air oven at 39°C for 30 min and centrifuged at 18,000-x *g* for 15 min at 4°C. In order to volatilize NH_3N, 72 m*M* K2CO3 were added in approximately 100 μg of OTD, PF, FP, PAB, FAB and ^{15}Nbackground samples, contained in 5- x 9- mm tin capsules (Elemental Microanalysis Limited, Okehampton, UK) (Brito et al. 2009). Following this step, ^{15}N analysis of the NAN of the OTD, PF, FP, PAB, FAB and ^{15}NB samples was done by combustion to nitrogen gas in an elemental analyzer and continuous flow isotope ratio-mass spectrometry (Reynal et al. 2005).

4.2.8 Calculations and Statistical Analysis

As a reported by Brito et al. (2009), the flow of nutrients to the omasum was calculated by multiplying DM flow by their concentration in OTD. Apparent and true rumen digestibility were calculated as described by Brito et al. (2009). Bacterial N yield using N-15 labelled ammonium sulphate ($^{15}NH_42SO_{4;}$ 10 atom percent excess N^{15}; Cambridge Isotope Laboratories) was calculated following Reynal et al. (2005). All data including ruminal fermentation, nutrient flow, intake, digestibility, omasal flow of N constituents and total tract nutrient digestibility values were analyzed as a Latin Square Design using the Mixed Model procedure of SAS (version 9.3; SAS Institute, Inc. Cary, N.C.) with animal being a random effect and treatment and period as fixed effects. The effects of meal type, WDDGS inclusion, and meal type x WDDGS interaction as a 2 x 2 factorial were tested. The Univariate procedure of SAS was used to check for normality assumptions. Significance was declared at $P<0.05$ and tendencies were declared when $0.05 < P \leq 0.10$.

4.3 Results and Discussion

4.3.1 Chemical Composition of the Experimental Diets

Chemical analysis of the meals used in this trial is reported in Table 4.1. The carinata meal similar to that in Trial 1 was higher in CP (42.1 ± 0.89% vs. 38.8 ± 0.56%) and lower in NDF (23.7 ± 2.19% vs. 29.0 ± 0.91%) and ADF (12.6 ± 0.96% vs. 21.0 ± 0.84%) content compared to canola meal. The WDDGS was lower (33.2 ± 0.38%) in CP content compared to carinata and canola, while ADF (14.9 ± 0.76%) and NDF (29.7 ± 1.88%) levels were lower relative to carinata and higher in comparison with canola. Xin and Yu (2013) reported that CP was higher (48 vs. 40%) and acid (11 vs. 19%) and neutral (19 vs. 28%) detergent fiber content lower for carinata meal compared to canola meal. Good (2018) in a comparison of canola versus SBM with or without

Table 4.1. The chemical profile of carinata meal (CRM), canola meal (CM) and wheat dried distillers's grains with solubles (WDDGS) using in Trial 3.

	Protein Sources		
Ingredients	Carinata Meal	Canola Meal	WDDGS
DM (%)	92.8 ± 0.65	90.3 ± 1.74	89.8 ± 0.48
OM (% DM)	91.8 ± 0.60	92.4 ± 0.11	94.1 ± 0.30
CP (% DM)	42.1 ± 0.89	38.8 ± 0.56	33.2 ± 0.38
SP (% DM)	9.4 ± 2.59	8.1 ± 2.46	4.9 ± 1.52
SP (% CP)	22.2 ± 5.93	20.9 ± 6.31	14.9 ± 4.67
ADICP[a] (% DM)	1.9 ± 0.25	3.2 ± 0.37	3.9 ± 0.44
ADICP (% CP)	4.5 ± 0.67	8.1 ± 0.91	11.6 ± 1.29
NDICP[b] (% DM)	5.4 ± 0.31	4.8 ± 0.20	5.3 ± 0.85
NDICP (% CP)	12.7 ± 0.83	12.4 ± 0.51	15.8 ± 2.37
ADF (% DM)	12.6 ± 0.96	21.0 ± 0.84	14.9 ± 0.76
NDF (% DM)	23.7 ± 2.19	29.0 ± 0.91	29.7 ± 1.88
Ca (% DM)	0.7 ± 0.05	0.9 ± 0.65	0.1 ± 0.01
P (% DM)	1.4 ± 0.05	0.9 ± 0.07	0.9 ± 0.06
Energy value (Mcal kg^{-1})			
NE_m	1.68 ± 0.01	1.42 ± 0.03	1.94 ± 0.04
NE_g	1.05 ± 0.01	0.84 ± 0.04	1.31 ± 0.04

Note: Analysis was conducted by Cumberland Valley Analytical Services (Hagerstown, MD) Carinata meal (n = 6); Canola meal (n = 6); WDDGS (n = 6)

[a]ADICP = Acid detergent insoluble CP

[b]NDICP = Neutral detergent insoluble CP

[c]Net Energy of Maintenance (NE_m) and Net Energy of Gain (NE_g) based on chemical analysis of feed and calculated according to the equations by Weiss et al. (1992); Mean ± SD.

WDDGS as a protein supplement for beef cattle, found CP content of 39.4 ± 0.8% for canola meal, 47.9 ± 1.1% for SBM and 33.7% for WDDGS. The WDDGS used by Good (2018) was the same batch used for the present study. The CP content of the WDDGS was lower than expected. This was likely due to the fact that the WDDGS was a blend of wheat/corn. Wheat DDGS typically has a CP content of 38 to 40% (Beliveau and McKinnon 2008; Walter et al. 2010) while corn DDGS is typically around 30% (Widyaratne and Zijlstra, 2007). Ethanol plants will blend wheat + corn prior to fermentation if the economics of corn relative to wheat are in favour of corn.

The carinata and canola had relatively similar SP (9.4 ± 2.59 % vs. 8.1 ± 2.46%), ADICP (1.9 ± 0.25 vs. 3.2 ± 0.37) and NDICP (5.4 ± 0.31 vs. 4.8 ± 0.20) (DM basis). The WDDGS was lower in SP (4.9 ± 1.52%), similar in NDICP (5.3 ± 0.85) and higher in ADICP (3.9 ± 0.44) relative to carinata meal and canola meal. In a comparison of carinata meal and canola meal, Xin and Yu (2013) reported that carinata meal had a higher SP (25.0 vs. 12.8%) and similar ADICP (0.59 vs. 1.34) and NDICP (4.57 vs. 6.91%) (DM basis). The high soluble CP of carinata meal in the Xin and Yu (2013) study can be attributed to processing. As opposed to the current study, the carinata meal of Xin and Yu (2013) was cold pressed and not solvent extracted and therefore not put through desolventizing and toasting. Good (2018) using similar diets as in the current study found SP levels for canola meal and WDDGS of 8.1 and 5.9% (DM basis). The author also reported similar ADIN (1.2 ± 0.1% vs. 1.1 ± 0.1%) and lower NDIN (1.4 ± 0.2% vs. 1.7 ± 0.1%) for diets containing canola meal compared to SBM.

The chemical composition of the experimental diets was calculated from chemical composition of ingredients to be isonitrogenous and isocaloric and to meet nutritional requirements for backgounding feedlot cattle with a target gain of 1.2 kg/d (NRC, 2000). Dietary CP levels averaged 14.5% (Table 4.2). As well, ADF and NDF levels were similar across diets.

Table 4.2. Composition and chemical analysis of the experimental diets fed to backgrounding beef heifers.

	Dietary Treatments			
	CRM	CM	CRM + WDDGS	CM + WDDGS
Ingredients (% DM)				
Barley grain	30.9	30.8	30.8	30.8
Carinata meal	9.3	-	5.0	-
Canola meal	-	10.0	-	5.0
Hay	20.6	20.5	20.5	20.5
Barley silage (var. Ranger)	32.2	31.7	31.7	31.7
WDDGS	-	-	5.0	5.0
Supplement	7.0	7.0	7.0	7.0
Supplement composition[a]				
Ground Barley	58.1	58.1	58.1	58.1
Prairie Pride Pellets	10.0	10.0	10.0	10
Limestone	23.5	23.5	23.5	23.5
Tallow	1.0	1.0	1.0	1.0
Mineral, vitamin premix	7.4	7.4	7.4	7.4
Ration Analysis[b]				
DM (%)	91.3 ± 0.44	91.3 ± 0.39	91.4 ± 0.42	91.4 ± 0.20
OM (% DM)	62.4 ± 1.94	62.7 ± 1.93	62.7 ± 1.92	62.7 ± 1.92
CP (% DM)	14.7 ± 0.14	14.6 ± 0.16	14.5 ± 0.14	14.3 ± 0.15
ADF (% DM)	20.0 ± 0.56	20.8 ± 0.50	20.0 ± 0.56	20.4 ± 0.53
NDF (% DM)	35.1 ± 3.02	35.6 ± 2.84	35.3 ± 2.95	35.6± 2.86
Ca (% DM)	1.0 ± 0.02	1.2 ± 0.08	1.1 ± 0.06	1.5 ± 0.07
P (% DM)	0.4 ± 0.01	0.4 ± 0.01	0.4 ± 0.01	0.4 ± 0.03
Energy value (Mcal kg^{-1})[c]				
NE_m	1.54 ± 0.03	1.49 ± 0.04	1.53 ± 0.03	1.51 ± 0.04
NE_g	0.97 ± 0.02	0.92 ± 0.03	1.96 ± 0.03	0.95 ± 0.03

Note: CRM = Carinata meal; CM = Canola meal; WDDGS = based dried distillers grains with solubles

[a]Supplement pellet was formulated to supply CP = 8.59%; crude fat = 2.72%, crude fibre = 4.65%, Ca = 10.43%, P = 0.27%, Mg = 1.95%, K = 0.53%, S = 0.11%, and Na = 1.50% of dietary DM, monensin = 467.89 mg /kg, Co = 5.0 mg/kg, Cu = 190.0 mg/kg, I = 8.70 mg/kg, Fe = 488.4 mg/kg, Mn = 569.7 mg/kg, Se = 2.45 mg/kg, Zn = 434.1 mg/kg, vitamin A = 43,525.57 IU/kg, vitamin D3 = 5,440.6 IU/kg, vitamin E = 652.88 IU/kg of supplement.

[b]Analysis was conducted by Cumberland Valley Analytical Services (Hagerstown, MD)

[c]Net Energy of Maintenance (NE_m) and Net Energy of Gain (NE_g) based on chemical analysis of feed and calculated according to the equations by Weiss et al. (1992); Mean ± SD.

This analysis of the total mixed rations is in agreement with McKinnon et al. (unpublished) study where similar levels of canola meal and carinata meal were fed. As diets were formulated to be isonitrogenous and isocaloric NE_m and NE_g values were similar across treatments.

4.3.2 Rumen Fermentation (NH_3-N, VFA, and Rumen pH).

Rumen fermentation characteristics are illustrated in Table 4.3. Ruminal NH_3-N (8.5 ± 0.58 mg dL^{-1}) concentration was not affected by treatment ($P > 0.05$). These results make sense in that all diets were formulated to be isonitrogenous. They also indicate that diets were similar in rumen degradability irrespective of protein source. They do however, contrast with the results of other studies where canola meal was included at graded levels (Nair et al. 2016; He et al. 2013). In these studies canola meal was fed at levels of 10% of DM or greater. As such one would expect high NH_3-N levels with such treatments.

There was no diet effect ($P > 0.05$) on acetate (68.6 ± 2.80 m*M*), or propionate (24.2 ± 1.69 m*M*) concentration in ruminal fluid (Table 4.3). Similarly, Good (2018) reported no differences on ruminal concentration of acetate and propionate in beef cattle fed canola meal or SBM with or without WDDGS at levels similar to that in the current trial. In contrast, in some studies where barley grain was replaced with canola meal (Nair et al. 2016) and with WDDGS at high inclusion rates (Beliveau and McKinnon 2009; Walter et al. 2012), an increase in acetate and a decrease in propionate was reported as the inclusion of these by-products increased in the diet. This can be explained by the fact that canola and WDDGS have higher protein and fiber content versus starch, as is the case with barley grain (Nair et al. 2015; Walter et al. 2010). Diets high in fiber content promote acetate and butyrate production, while diets with high starch content stimulate the production of propionate (Sutton et al. 2003).

Table 4.3. Effects of comparing carinata (CRM) and canola meal (CM) with or without wheat dried distiller's grains with solubles (WDDGS) on characteristics of ruminal fermentation in backgrounding beef heifers.

Item	Dietary Treatments				SEM	*P*-value		
	CRM	CM	CRM + WDDGS	CM + WDDGS		Meal Type	WDDGS	Meal Type x WDDGS
Ruminal NH_3-N (mg/dL^{-1})	9.2	7.9	8.3	8.7	0.74	0.67	0.99	0.41
VFA concentration (m*M* L^{-1})								
Acetate	65.4	68.1	72.2	68.8	1.58	0.89	0.13	0.20
Proprionate	23.6	26.5	24.2	22.5	1.34	0.99	0.14	0.24
Butyrate	12.6	13.2	14.4	14.4	0.88	0.57	0.03	0.64
Isobutyrate	1.1	1.0	1.0	1.2	0.05	0.41	0.51	<0.01
Valerate	1.3	1.4	1.5	1.3	0.09	0.77	0.57	0.04
Isovalerate	1.9	1.7	1.9	1.9	0.12	0.51	0.74	0.45
Total VFA (m*M* L^{-1})	104.6	112.5	114.6	111.3	3.05	0.93	0.30	0.07
Acetate:proprionate ratio	2.8	2.7	3.0	3.2	0.16	0.84	<0.01	0.39
Ruminal pH	6.4	6.6	6.4	6.7	0.06	0.77	0.82	0.28

Note: 2x2 factorial with main effects of meal type (CRM vs. CM), WWDGS inclusion (with vs. without WDDGS) and meal type x WDDGS interaction

Acetate, butyrate and proprionate are the main energy precursors for maintenance and production in ruminants (Sutton, 1968). Inclusion of WDDGS in carinata meal and canola meal diets increased (P = 0.03) butyrate concentration (12.9 ± 0.41 vs. 14.4 ± 0.04 m*M*). Walter et al. (2012) reported a quadratic increase in butyrate concentration in heifers fed WDDGS at levels up to 40% (DM basis). Since butyrate concentration increase with increasing amounts of fibre in the diet, the results of these studies can be explained by the replacement of barley grain by WDDGS, irrespective of inclusion levels fed. The interaction between meal type x WDDGS inclusion decreased isobutyrate (P < 0.01) concentration when WDDGS was added to carinata meal (1.1 vs. 1.0 m*M*) diets and increased isobutyrate (P < 0.01) concentration when WDDGS was included in canola meal (1.0 vs. 1.2 m*M*) diets. An interaction was also detected for valerate (P = 0.04) however, the meal type x WDDGS interaction was opposite to that of isobutyrate as valerate increased when WDDGS was added to carinata meal (1.3 vs. 1.5 m*M*) diets and decreased when WDDGS was added to canola meal (1.4 vs. 1.3 m*M*) diets. There was a trend (P = 0.07) for meal type x WDDGS interaction for total VFA concentration where VFA (m*M*) was higher when WDDGS was added to carinata meal (104.6 vs. 114.6 m*M*) diets and slightly lower when WDDGS was added to canola meal (112.5 vs.111.3 m*M*) diets. Inclusion of WDDGS increased (P<0.01) acetate: proprionate ratio (2.7 ± 0.06 vs. 3.1 ± 0.09 m*M*). This may be due to the high fibre nature of WDDGS. While inclusion levels were low and no effect was seen on diet ADF and NDF levels (Table 4.2), addition of WDDGS did result in a trend (P = 0.09) to increased NDF intake (Table 4.4). Higher fiber intakes are known to be associated with higher acetate: propionate rations (Sutton et al. 2003). Ruminal pH averaged 6.5 ± 0.12 across diets with no effect (P > 0.05) of treatment. The minimal effects of treatment on total and individual VFA levels and ruminal pH

further suggest that there were minimal differences between treatments in rumen fermentability (Table 4.3).

4.3.3 Intake, Digestibility and Omasal Flow of Dietary Nutrients

Intake, digestibility and omasal flow of dietary nutrients are illustrated in Table 4.4. No treatment effects ($P > 0.05$) were observed on intake of DM (10.5 ± 0.21 kg d^{-1}) OM (9.6 ±0.19 kg d^{-1}), or NDF (3.8 ± 0.07 kg d^{-1}). In addition, omasal flow of DM (6.9 ± 0.23 kg d^{-1}), OM (5.6 ± 0.22 kg d^{-1}), and NDF (2.2 ± 0.08 kg d^{-1}) were not different between treatments ($P > 0.05$). There were also no treatment differences ($P > 0.05$) in apparent ruminal digestion of DM (3.6 ± 0.38 kg d^{-1}; 33.7 ± 3.37%), OM (4.0 ± 0.35 kg d^{-1}; 41.2 ± 3.24%), NDF (1.5 ± 0.05 kg d^{-1}; 40.3 ± 0.59%), or in OM (6.1 ± 0.39 kg d^{-1}; 63.5 ± 2.91%) truly digested in the rumen.

Currently, there are no published data regarding nutrient flow and ruminal digestion in beef cattle fed CRM versus canola meal with or without WDDGS. However, Good (2018) conducted a similar trial to the current study comparing canola meal versus soybean meal with or without WDDGS as protein supplements. Unlike the current trial, these authors found lower ($P = 0.01$) DMI for heifers fed WDDGS. They also reported a higher ($P = 0.04$) apparent ruminal digestibility of DM and OM for heifers fed canola meal relative to SBM. As with the current study there was no effect of protein supplement on apparent digestion of NDF. Relative to the current study apparent ruminal digestion of DM, OM, and NDF was reduced, even though diets were somewhat similar. These differences can be explained due to variations in omasal collection, which can affect marker recovery, reconstitution of OTD and consequently the estimation of nutrients flowing out of the rumen (Titgemeyer, 1997) and possibly the age of animals, as the heifers in the study of Good (2018) were about six months ol

Table 4.4. Nutrient flow from and digestion in the rumen of beef cattle fed carinata (CRM) versus canola meal (CM) with or without wheat dried distiller's grains with solubles (WDDGS).

Item	Dietary Treatments				SEM	*P*-value		
	CRM	CM	CRM + WDDGS	CM + WDDGS		Meal Type	WDDGS	Meal Type x WDDGS
DM								
Intake, kg/d^{-1}	10.4	10.6	10.5	10.5	0.33	0.66	0.98	0.73
Omasal flow kg/d^{-1}	6.7	7.1	6.9	6.9	0.28	0.38	0.99	0.28
Apparent digestion, kg/d^{-1}	3.6	3.6	3.5	3.6	0.53	0.95	0.85	0.40
Apparent digestion, % of DM intake	34.3	33.2	33.5	34.0	4.09	0.84	0.93	0.40
OM								
Intake, kg/d^{-1}	9.4	9.7	9.5	9.6	0.29	0.46	0.81	0.92
Omasal flow kg/d^{-1}	5.4	5.7	5.6	5.5	0.22	0.46	0.92	0.39
Apparent digestion, kg/d^{-1}	3.8	3.6	4.1	4.4	0.61	0.97	0.89	0.43
Apparent digestion, % of OM intake	39.2	38.2	42.1	45.4	5.26	0.86	0.97	0.42
True digestion kg/d^{-1}	5.8	5.7	6.5	6.4	0.46	0.56	0.80	0.97
True digestion % OM intake	61.3	60.7	65.8	66.2	3.12	0.11	0.98	0.84
NDF								
Intake, kg/d^{-1}	3.7	3.7	3.9	3.8	0.06	0.86	0.09	0.71
Omasal flow, kg/d^{-1}	2.2	2.2	2.3	2.3	0.24	0.99	0.89	0.33
Apparent digestion, kg/d^{-1}	1.5	1.6	1.6	1.5	0.35	0.34	0.71	0.89
Apparent digestion, % of NDF intake	40.7	40.7	39.4	40.4	8.54	0.96	0.93	0.96

Note: 2x2 factorial with main effects of meal type (CRM vs. CM), WWDGS inclusion (with vs. without WDDGS) and meal type x WDDGS interaction

The results of the present study in terms of DMI agree with previous study with dairy cows using similar techniques (Chibisa et al. 2012). These authors reported no differences on DMI of cows fed canola meal in comparison with those fed increased levels of WDDGS. However, the intakes of the current study are lower in comparison with trials using dairy cows (Brito et al. 2009; Chibisa et al. 2012). Consequently, these studies reported greater omasal DM, OM and NDF flow to the small intestine (Chibisa et al. 2012). However, apparent digestion of DM was reduced relative to the current study while that of OM and NDF were similar.

Data on apparent digestion of ADF is not presented, as these values were higher than corresponding values for NDF. As this is biologically not possible, ADF values were omitted. Potential reasons for this discrepancy include errors in marker recovery and reconstitution of the OTD which may have led to overestimation of ADF in the omasal digesta (Titgemeyer 1997; Rotta et al. 2014).

4.3.4 Omasal Nitrogen Flow and Microbial Protein Synthesis

No meal x WDDGS interactions were detected on N digestion, as such only main effects are discussed. Omasal nitrogen flow and nitrogen constituents are presented in Table 4.5. As there were no differences in DMI and the fact that diets were isonitrogenous, there were no treatment differences ($P > 0.05$) in nitrogen intake (241.3 ± 4.10 g d^{-1}) and N flow at the omasal canal (239.4 ± 15.61 g d^{-1}). However, nitrogen apparently ($P = 0.09$) and truly ($P = 0.04$) digested in the rumen was higher when WDDGS was included in the carinata meal and canola meal diets. The quantity of N apparently digested in the rumen was negative for diets containing only carinata meal and canola meal, indicating that N outflow was greater than N intake. Consequently, carinata meal and canola meal diets had greater N apparent digested in the rumen suggesting N used for microbial

Table 4.5. Intake, digestibility, and omasal flow of N constituents in beef cattle fed carinata (CRM) and canola meal (CM) with or without wheat dried distiller's grains with solubles (WDDGS).

Item	Dietary Treatments				SEM	*P*-value		
	CRM	CM	CRM + WDDGS	CM + WDDGS		Meal Type	WDDGS	Meal Type x WDDGS
N								
Intake, g/d^{-1}	239.2	238.0	247.2	240.8	2.85	0.24	0.11	0.40
Apparently digested in the rumen, g/d^{-1}	-12.0	-8.2	3.4	24.4	11.33	0.34	0.09	0.50
Apparently digested in the rumen, % of N intake	-5.8	-4.2	1.1	9.9	4.90	0.36	0.09	0.52
Truly digested in the rumen, g/d^{-1}	154.4	154.6	178.3	177.5	8.88	0.98	0.04	0.96
Truly digested in the rumen, % of N intake	64.6	65.5	72.2	73.8	3.82	0.76	0.09	0.93
RDP supply								
g/d^{-1}	1099.7	1091.2	1263.9	1265.7	62.31	0.96	0.02	0.93
% of DM intake	15.7	15.5	18.5	19.5	1.22	0.78	0.04	0.68
Flow at Omasal Canal								
N								
g/d^{-1}	251.2	246.2	243.8	216.5	9.56	0.16	0.12	0.31
% of N intake	105.8	104.2	98.9	90.1	4.90	0.36	0.09	0.53
NH_3-N, g/d^{-1}	21.5	19.9	23.9	25.0	3.42	0.93	0.25	0.67
NAN								
g/d^{-1}	229.7	226.2	219.8	191.4	8.64	0.13	0.04	0.22
% of N intake	96.8	95.8	89.1	79.8	4.41	0.32	0.04	0.42

Note: 2x2 factorial with main effects of meal type (CRM vs. CM), WWDGS inclusion (with vs. without WDDGS) and meal type x WDDGS interaction

Table 4.5.cont. Intake, digestibility, and omasal flow of N constituents in beef cattle fed carinata (CRM) and canola meal (CM) with or without wheat dried distiller's grains with solubles (WDDGS).

Item	Dietary Treatments				SEM	*P*-value		
	CRM	CM	CRM + WDDGS	CM + WDDGS		Meal Type	WDDGS	Meal Type x WDDGS
NANBN								
g/d	63.2	63.4	45.0	38.3	10.93	0.77	0.08	0.75
% of NAN flow	27.5	28.7	20.6	20.1	4.71	0.95	0.13	0.85
% of N intake	26.4	26.1	18.1	16.0	4.25	0.76	0.05	0.83
% of DM intake	0.9	0.9	0.7	0.6	0.18	0.91	0.13	0.74
RUP								
g/d	395.3	396.3	281.1	239.4	68.28	0.76	0.08	0.75
% of DM intake	5.6	5.9	4.2	3.7	1.12	0.91	0.13	0.74
FAB NAN								
g/d	75.6	70.7	91.3	74.3	6.48	0.17	0.22	0.42
% of total bacterial NAN	45.8	46.4	52.5	49.1	2.78	0.62	0.13	0.49
PAB NAN								
g/d	90.8	92.1	83.6	78.9	10.13	0.86	0.32	0.77
% of total bacterial NAN	54.2	53.6	47.5	50.9	2.79	0.62	0.13	0.49
Total Bacterial NAN								
g/d	166.5	162.8	174.9	153.1	12.69	0.34	0.96	0.49
% of NAN flow	73.2	81.6	80.4	72.2	4.71	0.95	0.13	0.85
Microbial efficiency								
g of microbial N/kg OMTDR	29.3	27.1	27.3	27.4	3.13	0.65	0.28	0.57

Note: 2x2 factorial with main effects of meal type (CRM vs. CM), WWDGS inclusion (with vs. without WDDGS) and meal type x WDDGS interaction

protein production or possibly N recycling was greater than N intake. On the other hand, N apparently digested in the rumen was slightly positive for diets containing a blend of carinata meal + WDDGS and canola meal + WDDGS respectively, reflecting that N intake was greater than N outflow. In contrast, N truly digested in the rumen whether expressed as g/d ($P = 0.04$) or as a % of N intake ($P = 0.09$) was greater for diets containing WDDGS. Reflecting these differences, RDP supply when expressed as g/d ($P = 0.02$) or as % of DMI ($P = 0.04$) was higher when WDDGS was included in the carinata meal and canola meal diets. The flow of NH_3-N at omasal canal (22.6 ± 2.30 g d^{-1}); however, was similar ($P > 0.05$) among treatments.

There have been no previous studies that have reported intake and omasal flow of N constituents in beef cattle fed carinata meal and canola meal with or without WDDGS. However, the relative extent to which WDDGS was digested in the rumen was unexpected as it is traditionally thought of as a source of RUP. Chibisa et al. (2012) for example reported no effect of WDDGS inclusion on N apparently or truly digested in the rumen. The improvement in N truly digested in the rumen by diets containing WDDGS in the present trial can be explained by several factors. First, the carinata meal, canola meal and WDDGS used in this trial were relatively similar in SP, ADICP and NDICP content when expressed as a % of DM (Table 4.1). Thus, one would not expect large differences in rumen degradability. This is also supported by the rumen NH_3-N results where there was no difference between treatments. Second, Good (2018) reported the results of an in situ trial comparing RDP and RUP values for the canola meal and WDDGS used in the present trial. It was reported that WDDGS had the highest SP fraction (25.7 vs. 6.8%; $P < 0.05$) and lowest U (undegradable fraction) (5.3 vs. 8.6%) in comparison with canola meal. There were no differences ($P < 0.05$) in effective degradability (52.1 vs. 56.0%) and rumen undegradable protein (46.9 vs. 44.0%) content between WDDGS and canola meal (Good, 2018). These results

agree with Maxin et al. 2013a, who found similar RUP degradability for canola meal to that of WDDGS. These results help to explain the increase in rumen N availability of the WDDGS in this study. There are many factors that affect the RDP/RUP content of a feedstuff. For example, the RUP values of canola meal and WDDGS have changed over time likely due to effects of heating in the case of WDDGS and the addition of foreign materials such as gums and screenings during processing of canola meal (Maxin et al. 2013a; Good, 2018).

Rumen nitrogen outflow in terms of total N (g/d) was not different between treatments; however, when expressed as a % of N intake, it tended ($P = 0.09$) to decrease when WDDGS was added to the diets. Similarly, rumen outflow of NAN expressed as g/d or as a % of N intake decreased (P = 0.04) when WDDGS was added to the diets. As well, rumen outflow of NANBN ($P = 0.08$) and rumen outflow of RUP ($P = 0.08$) decreased when WDDGS was included in the carinata meal and canola meal diets. These results reflect the fact that diets formulated with WDDGS had increased apparent and truly ruminal digestion of N as discussed above. Good (2018) fed similar diets did not see any effect of feeding WDDGS with canola meal or SBM on omasal flow of NAN, NANBN or RUP supply. Levels of WDDGS fed by Good (2018) were similar to the current study. In contrast when graded levels of WDDGS were fed to dairy cows, linear increases in NANBN supply were reported as the level of WDDGS increased in the diet (Chibisa et al. 2012).

No treatments differences ($P > 0.05$) were noted in omasal fluid or particle associated bacteria or in total bacterial NAN. These results suggest that all treatments provided sufficient amounts of protein and energy for microbial protein synthesis. As a result, there was no effect ($P > 0.05$) on microbial efficiency (27.8 ± 1.04g kg^{-1} OMTDR) between experimental diets. In a comparison of canola meal to SBM with or without WDDGS as a protein supplement for beef

cattle, Good (2018) also reported no effects on total bacterial NAN flow and microbial efficiency. However, total bacterial NAN flow and microbial efficiency in the current trial as well as that of Good (2018) are higher than that reported by Owens et al. (2014) with beef cattle fed corn silage, grass silage or whole- crop wheat. These differences are likely due to differences in DMI between trials. Since lower DMI may decrease passage rate, microbial efficiency is reduced by the increased microbial protein and energy requirements for ruminal digestion of feedstuffs (Russel et al. 1992). Despite the differences in DM intake and source of dietary protein, the current results are in accordance with studies that have been done with dairy cows (Brito et al. 2006; Reynal et al. 2005; Chibisa et al. 2012). For example, Chibisa et al. (2012) reported a total bacterial NAN of 69.9 ± 2.35% of NAN flow, which is comparable to current data. It could be concluded that carinata meal when fed at levels as used in the current trial is equal to canola meal as a N source for microbial CP synthesis in backgrounding diets and that WDDGS addition did not influence microbial efficiency.

4.3.5 Total Tract Digestibility Characteristics

Total tract digestibility coefficients are illustrated in Table 4.6. No effect ($P > 0.05$) of treatment on apparent nutrient digestibility of DM (65.3 ± 0.97%), OM (67.8 ± 0.99%) and CP (66.1 ± 1.27%), was found. Xin and Yu (2013) in an in vitro digestibility study comparing carinata and canola meal reported total digestibility of 86.24 vs. 79.54% for OM and 93.41 vs. 88.59% for CP, respectively. Good (2018) found no differences ($P > 0.05$) on DM (61.13 ± 0.57%), OM (62.7 ± 0.8%), and CP (70.1 ± 0.8%) digestibility of backgrounding heifers fed diets formulated with canola meal or SBM with or without WDDGS at similar levels to the current study. Studies where cattle were fed higher levels of conventional protein supplements such as canola meal, corn and

Table 4.6. Effects of comparing carinata (CRM) and canola meal (CM) with or without wheat dried distiller's grains with solubles (WDDGS) on dry matter and organic matter intake and apparent nutrient digestibility coefficients (%) in backgrounding beef heifers.

	Dietary Treatments					*P*-value		
Item	CRM	CM	CRM + WDDGS	CM + WDDGS	SEM	Meal Type	WDDGS	Meal Type x WDDGS
Dry matter intake kg/d^{-1}	10.3	10.4	10.5	10.6	0.45	0.67	0.88	0.98
Dry matter intake %BW	2.3	2.3	2.3	2.3	0.06	0.68	0.86	0.47
Organic matter intake kg/d	9.5	9.6	9.6	9.6	0.35	0.94	0.99	0.96
Organic matter intake %BW	2.1	2.1	2.1	2.1	0.06	0.67	0.76	0.54
Apparent nutrient digestibility %DM								
Dry matter	64.1	66.3	65.9	65.0	1.75	0.85	0.68	0.35
Organic matter	66.6	68.8	68.3	67.4	1.62	0.91	0.63	0.28
Crude protein	65.2	67.8	66.3	65.0	2.08	0.60	0.67	0.26
Acid detergent fiber	38.2	43.3	40.7	40.5	3.59	0.97	0.48	0.44
Neutral detergent fiber	45.3	47.0	48.0	48.0	4.32	0.67	0.99	0.75
Gross energy	63.8	67.0	66.2	65.4	1.55	0.78	0.45	0.21
Gross Energy Mcal//kg	4.10	4.11	4.12	4.13	0.001	<0.01	<0.01	0.34
Digestible energy (Mcal kg/d^{-1})	2.6	2.8	2.7	2.7	2.75	0.80	0.53	0.30
Digestible energy intake (Mcal kg/d^{-1})	27.3	28.7	29.4	28.7	1.78	0.59	0.86	0.56

Note: 2x2 factorial with main effects of meal type (CRM vs. CM), WWDGS inclusion (with vs. without WDDGS) and meal type x WDDGS interaction

WDDGS (up to 40%) showed increased CP digestibility (Zinn et al. 1998; Walter et al. 2012; Nair et al. 2015). Higher CP digestibility of cattle supplemented with protein above the animal's requirements is likely related to increased ruminal nitrogen availability, which provides for enhanced microbial activity leading to high rumen NH_3-N levels and likely increased loss of N as urea (Mutsvangwa et al. 2016). Additionally, no treatment differences ($P>0.05$) in total tract ADF (40.7 ± 2.11%) or NDF digestibility (47.1 ± 1.27%) were found among experimental diets. As this study targeted the CP requirements of the animal or slightly above, it is not surprising that total tract digestibility characteristics were not affected. The ADF (48.1%) and NDF (50.5%) total tract digestibility results in the current study are lower than that reported by Gozho et al. (2008) who fed beef heifers at 8.78% of canola meal (DM basis). Walter et al. (2012) also reported higher ADF (60.18%) and NDF (74,56%) digestibility values for cattle fed WDDGS at 20% of the diet (DM basis). However, the ADF (40.7%) and NDF (47.1%) digestibility results of the current study are higher compared to Nair et al. (2015) who found ADF and NDF digestibility values of 34.1% and 42.6%, respectively in cattle fed 10% canola meal.

Gross energy (mcal/kg) of diets containing CM was greater ($P < 0.01$) relative to those containing CRM. The inclusion of WDDGS increased ($P < 0.01$) gross energy in the diets, gross energy digestibility (65.6 ± 1.34%), digestible energy (2.7 ± 0.05 Mcal kg^{-1}) and digestible energy intake (28.5 ± 0.88 Mcal kg^{-1}) were not different between treatments ($P > 0.05$) (Table 4.6). This could be attributed to the similarly between diets in terms of basal feed ingredients and to the fact that DMI was not affected by treatment.

4.4 Conclusion

The results of this study indicate that carinata meal is similar to canola meal in terms of its effect on rumen fermentation, omasal flow, microbial protein synthesis and total tract digestibility characteristics of growing heifers. Diets supplemented with carinata meal and canola meal had greater N apparently digested in the rumen. However, the inclusion of WDDGS increased N truly digested in the rumen. Consequently, RDP supply increased and omasal flow of N (% of N intake), NAN, NANBN and RUP decreased with inclusion of WDDGS in the diets. These results are likely due to the fact that carinata meal, canola meal and WDDGS used in this trial were similar in SP, ADICP and NDICP. However, total bacterial NAN and microbial efficiency were not different between treatments indicating that carinata meal, canola meal and WDDGS provided sufficient levels of RDP for microbial protein synthesis. Therefore, carinata meal is an acceptable substitute for canola meal as a protein supplement for growing heifers and there is no benefit to adding WDDGS as a rumen undegradable protein source in such production situations.

5.0 GENERAL DISCUSSION

The research carried out in this thesis was comprised of two feedlot and one metabolic trials with the objective to: 1) compare carinata meal to canola meal as a protein source in the diet of growing beef steers; 2) compare the value of carinata meal to canola meal as a protein supplement when fed alone or in combination with WDDGS in finishing rations of yearling steers and 3) to measure the value of carinata meal relative to canola meal when fed alone or in combination with WDDGS on rumen fermentation, total tract nutrient utilization, omasal nutrient flow and MCP synthesis and efficiency. Similar to values reported by Xin and Yu (2013) and McKinnon et al. (unpublished), carinata meal used in the Trial 1 (43.9 ± 2.55 vs. 39.8 ± 2.55) and Trial 2 (46.9 ± 4.07 vs. 41.6 ± 0.23) were higher in CP content relative to canola meal. During Trial 1, carinata meal was lower in NDF (21.4 ± 1.65 vs. 29.2 ± 0.21) and ADF (11.8 ± 0.85 vs. 20.4 ± 0.85) content than canola meal. Carinata meal utilized in Trial 2 was lower in NDF (21.6 ± 0.56 vs. 28.4 ± 0.67) and in ADF (11.8 ± 0.30 vs. 20.0 ± 1.06) content in comparison to canola meal. The WDDGS was composed by 40.1 ± 0.51% CP, 37.2 ± 1.21% NDF and 13.2 ± 1.17% ADF (DM basis).

Trial 1 was designed to compare the performance of growing beef steers fed carinata meal as a protein supplement relative to those fed canola meal at two inclusion levels (7.5 or 15% DM). It lasted for 97 days using 360 calves randomly assigned to 12 pens (30 head per pen). The inclusion of carinata meal in the backgrounding diets had no effect on initial (321.8 ± 24.27 kg) and final (427.8 ± 29.76 kg) shrunk body weight, ADG (1.10 ± 0.02 kg), DMI (7.7 ± 0.24 kg/d), and G:F (0.14 ± 0.01). These results indicate that carinata meal at 7.5 or 15% DM (basis) is equal to canola meal as protein supplement for growing cattle. There were no benefits to feeding carinata meal or canola meal at 15% relative to feeding at 10% of diet DM. While

there are no published data on carinata meal as protein supplement for backgrounding cattle, McKinnon et al. (unpublished) reported that feedlot steers fed cold pressed carinata meal, showed the poorest performance in the first 42 days of feeding relative to those fed canola meal and a blend of carinata and canola meal. However in the remaining 37 days of the trial, there was no effect of treatment on animal performance. These results are attributed to high glucosinolate levels (128 μmol/g) of carinata meal used in this trial that may have generated palatability issues. Due to the fact that in the present study carinata seed was pressed, solvent extracted, subsequently desolventized and toasted, glucosinolate levels were markedly lower in comparison to that of McKinnon et al. (unpublished). As such glucosinolate levels did not impact performance in the current trial. Diets containing high concentration of these sulphur-containing compounds may induce palatability issues; decrease feed intake and consequently performance of cattle. Furthermore relative to published trials where other high protein by-product feeds have been fed, cattle in this study fed carinata meal at 7.5% or 15% had comparable ADG, DMI and G: F ratios. These results indicate that for growing cattle, carinata meal is equivalent to canola meal as a protein supplement.

In Trial 2, yearling steers were fed finishing diets with the objective of comparing the value of carinata meal to canola meal as a protein supplement when fed alone or in combination with WDDGS. The trial consisted of 125 days with a total of 250 cross-bred steers randomly assigned to 25 pens (10 head per pen). A fifth treatment involved WDDGS as the sole protein source. Two statistical models were run. The first was analyzed as a CRD with a pen as experimental unit while in the second the WDDGS diet was dropped and the effects of meal type, WDDGS inclusion, and meal type x WDDGS interaction were analyzed as a 2 x 2 factorial. There were no dietary effects on initial (418.7 ± 26.7 kg) and final (649.8 ± 44.1 kg) shrunk body weight, ADG (1.85 ± 0.05 kg), DMI (11.92 ± 0.28 kg/d), and

G:F (0.16 ± 0.01), NE_m (1.92 ± 0.02) and NE_g (1.28 ± 0.02 kg). Meal type, WDDGS inclusion or meal type x WDDGS interaction did not affect performance parameters (P > 0.05). As with growing cattle, there are no published results with finishing cattle fed carinata meal. However, when performance results of the current trial including ADG, DMI and G: F ratios where compared to similar trials where canola meal or WDDGS was fed, it was found that results were comparable. Therefore, it could be concluded that carinata meal is a suitable protein source for finishing rations without adverse effects on animal health and performance.

In terms of carcass characteristics, canola meal improved HCW and consequently dressing percentage compared to carinata meal. When analyzed as a 2x2 factorial the inclusion of WDDGS decreased dressing % and increased fat deposition. The reason for this effect of WDDGS on carcass fat partitioning is unclear. Particularly when you consider that the levels fed were relatively low. Other studies with WDDGS have found higher levels of carcass grade fat and increased dressing percentage when backgrounding and finishing cattle, respectively were fed higher levels of WDDGS (i.e. 20 to 60% of the diet DM) (Gibb et al. 2008; Walter et al. 2010).

The objective of Trial 3 was to measure the value of carinata meal relative to canola meal fed alone or in combination with WDDGS on rumen fermentation, omasal flow, microbial protein synthesis and total tract nutrient utilization. Four 4 ruminally cannulated heifers in a Latin square design were fed a barley-based backgrounding diet with CRM (9.2% DM); CM (10.0% DM); CRM (5.0% DM) + WDDGS (5.3 DM); or CM (5.0% DM) + WDDGS (5.3 DM) as protein sources. Samples of rumen, omasum and total tract digesta were collected in order to determine ruminal fermentation parameters, digest flow and nutrient digestibility. Omasal digesta flow and nutrient digestibility were measured with the triple marker technique using Cr,

Yb and iNDF. Microbial protein synthesis was determined using nitrogen labelled ammonium sulphate.

The nutrient profile of carinata meal in terms of CP (42.1 ± 0.89% vs. 38.8 ± 0.56%), NDF (23.7 ± 2.19% vs. 29.0 ± 0.91%) and ADF (12.6 ± 0.96% vs. 21.0 ± 0.84%) relative to canola meal is in accordance with Trial 2. However WDDGS is somewhat lower in CP (33.2 ± 0.38% vs. 40.0 ± 0.71% CP) and NDF (29.7± 1.88% vs. 37.2 ± 1.21%) and higher in ADF (14.9± 0.76% vs. 13.2 ± 1.17%) compared to WDDGS used in Trial 2. This is likely due to the fact that a blend of wheat/corn was used in the production of WWDGS used in this trial. The low CP content of corn grain will result in lower CP content of ethanol by-products following fermentation (Widyaratne and Zijlstra, 2007).

There were no differences between CRM and CM dietary treatments (P>0.05) on ruminal fermentation characteristics including ruminal ammonia (8.5 ± 0.58 mg dL^{-1}), total VFA (110.7 ± 4.33 m*M*), acetate (68.6 ± 2.80 m*M*), propionate (24.2 ± 1.69 m*M*), butyrate (13.6 ± 0.92 m*M*) and ruminal pH (6.5 ± 0.12). Inclusion of WDDGS increased (P = 0.03) butyrate (12.9 ± 0.41 vs. 14.4 ± 0.04 m*M*) concentration and acetate: proprionate ratio (P < 0.01); (2.7 ± 0.06 vs. 3.1 ± 0.09 m*M*) in the CRM and CM diets. Such changes are consistent with the trend for a higher NDF intake on the WDDGS diets. However, overall ruminal fermentation was not affected by dietary treatments, indicating that protein sources fed were similar in ruminal degradability.

Additionally, diets supplemented with CRM and CM tended (P = 0.09) to present greater N apparently digested in the rumen (-10.0 ± 2.73 vs. 13.9 ± 14.81 g d^{-1}; -5.0 ± 1.15 vs. 5.5 ± 6.19 %) compared to diets with WDDGS. In contrast, the inclusion of WDDGS increased (P = 0.04) and tended to increase (P = 0.09) N truly digested in the rumen (154.5 ± 0.16 vs. 177.9 ± 0.55 g

d^{-1}; 65.1 ± 0.66 vs. 73.0 ± 1.17%). Consequently, RDP supply (1095.5 ± 6.05 vs. 1264.8 ± 1.22 g d^{-1}; 15.6 ± 0.13 vs. 19.0 ± 0.70 %) increased (P = 0.02; P = 0.04) with inclusion of WDDGS in the diets. Also, diets containing WDDGS decreased (P = 0.04) NAN rumen outflow (228.0 ± 2.45 vs. 205.6 ± 20.07 g d^{-1}; 96.3 ± 0.71 vs. 84.5± 6.56. These results point to the fact that adding WDDGS to the diet, even at relatively low levels increased rumen fermentability of dietary protein. Previous studies on the rumen fermentation of WDDGS have shown that this protein source is a relatively good source of RUP (Mulrooney et al. 2009; Nuez-Ortin and Yu, 2010; Chibisa et al. 2012). There are several reasons for this unexpected result. These include the fact that meals used in this trial were similar in SP, ADICP and NDICP and previous research which showed that CM and WDDGS were similar in ruminal degradability (Good, 2018). Total bacterial NAN and microbial efficiency were not different (P > 0.05) between treatments.

Regardless of the improvement in ruminal fermentation due to the WDDGS inclusion in the experimental diets, we did not see any treatment differences (P > 0.05) on intake of DM (10.5 ± 0.21 kg d^{-1}), apparent digestion of DM (33.7 ± 3.37%), OM (41.2 ± 3.24%), NDF (40.3 ± 0.59%) and true digestion of OM (63.5 ± 2.91%) in the rumen. Similarly, total tract digestibility of DM (65.3 ± 0.97%), OM (67.8 ± 0.99%), or NDF (47.1 ± 1.27%) was similar (P > 0.05) between dietary treatments. These results reflect the fact that diets were similar in ingredients and supplied similar levels of digestible energy (2.7 ± 0.05 Mcal kg^{-1}).

Based on these results it can be concluded that carinata meal is a suitable substitute for canola meal as a protein supplement for backgrounding and finishing beef cattle diets. In summary, cattle fed carinata meal in backgrounding and finishing diets performed equally as well cattle fed canola meal. Rumen fermentation characteristics and MCP synthesis were similar for heifers fed carinata meal or canola meal with similar NAN flow to the small intestine to be

absorbed as a metabolizable protein.

Further research is required to:

1) Measure the influence of different temperatures and chemical treatments during carinata seed processing on glucosinolate content and the resulting effects on ruminal and post-ruminal degradability of carinata meal.

2) Compare apparent and true ruminal and post-ruminal digestibility of carinata meal CP with current industry samples of WDDGS and canola meal.

3) Compare carinata meal in terms of performance, carcass traits, rumen fermentation, omasal flow, and microbial protein synthesis with other common protein sources such as soybean meal, corn DDGS or urea based diets.

4) Measure ruminal fermentation, microbial protein synthesis, omasal flow and milk production in dairy cows fed carinata meal.

5) Determine intestinal amino acid supply in beef and dairy cattle fed carinata meal.

6.0 GENERAL CONCLUSION

Carinata has agronomical and economic advantages in comparison with canola as a potential oil source for biofuel production for the aviation industry. Current processing of carinata for oil results in a low glucosinolate meal that is chemically superior to canola meal. The results from the present study indicate that carinata meal is equivalent to canola meal as a protein supplement for backgrounding beef cattle. Cattle fed carinata meal in both backgrounding and finishing phases had equal performance to those fed canola meal. However, dressing percentage and HCW were greater in cattle fed canola meal relative to those fed carinata meal. Carinata meal, relative to canola meal, did not affect rumen fermentation, nutrient utilization or microbial protein synthesis. The supply of metabolizable protein to the small intestine was similar on carinata meal and canola meal based diets. There was no benefit to adding WDDGS as a rumen undegradable protein source. These results indicate carinata meal is an attractive feedstuff for beef cattle. Further research is required in order to determine the influence of heat during the seed processing on carinata meal degradability, and to compare the performance and ruminal fermentation parameters and determine intestinal amino acid supply of cattle fed carinata meal to those fed more traditional protein sources such as WDDGS, soybean meal, corn DGGS or urea based diets in beef and dairy cows.

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