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Effects of Increasing Dietary Levels of Carinata Meal on Feeding Behavior, Performance and Carcass Characteristics of Beef Growing Steers

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EFFECTS OF INCREASING DIETARY LEVELS OF CARINATA MEAL ON FEEDING BEHAVIOR, PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF GROWING STEERS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science in Animal Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusion of the major department.

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"To be grateful is to recognize the love of God in everything he has given us……
He has given us everything.
Every breath he draw is a gift of his love; every moment of existence is a grace,
for it brings with it immense graces."
Thomas Merton

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ABBREVIATIONS

AA	amino acid
ADF	acid detergent fiber
ADG	average daily gain
BF	back fat
BW	body weight
Ca	calcium
CM	carinata meal
CM5	carinata meal 5 % inclusion
CM10	carinata meal 10 % inclusion
CM15	carinata meal 15 % inclusion
CONT	control group
CP	crude protein
d	day
DDG	dry distillers grain
DDGS	dry distillers grain with solubles
DIP	degradable intake protein
DM	dry matter
DMB	dry matter basis
DMI	dry matter intake
DMMS	dry matter meal size
EA	erucic acid
EE	ether extract

EDDI	ethylenediamine dihydriodide
FDA	Food and Drug Administration
g	gram
G: F	gain to feed ratio
GLs	glucosinolates
h	hour
ha	hectare
HCW	hot carcass weight
HMC	high moisture corn
IMI	inter-meal interval
kg	kilogram
KPH	kidney, pelvic, and heart fat
m	meter
MARB	marbling
Mcal	megacalorie
mg	milligram
MD	meal duration
min	minutes
MP	metabolizable protein
µmol	micromolecule
MS	meal size
NDF	neutral detergent fiber
NEm	net energy for maintenance

NEg	net energy for gain
NOM	number of meals
NPN	non-protein nitrogen
OM	organic matter
P	phosphorus
ppm	parts per million
RDP	rumen degradable protein
REA	ribeye area
RIC	roughage intake control
RUP	rumen undegradable protein
SBM	soybean meal
SEM	standard error mean
SFM	sunflower meal
SD	standard deviation
T3	triiodothyronine
T4	thyroxine
TMR	total mixed ration
USDA	United States Department of Agriculture
WDG	wet distillers grain
wt	weight
YG	USDA yield grade

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ABSTRACT

EFFECTS OF INCREASING DIETARY LEVELS OF CARINATA MEAL ON FEEDING BEHAVIOR, PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF GROWING STEERS

ALEJANDRO C. CASELLA

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The objectives of the present study are to evaluate feeding behavior, animal performance and carcass characteristics of beef growing steers fed increasing amounts of carinata meal (CM). Due to the high protein content of the CM after the oil extraction for biofuel there is an opportunity to use it as a protein supplementation in beef cattle. Twenty-four steers blocked by weight were assigned to four corn-based diets (n = 6 animals per treatment). In the three treatment diets, carinata meal replaced high-moisture corn at 5, 10, or 15%. The diets were fed using the Insentec RIC system for 138 days. During the feeding period, individual feed disappearance, feeding behaviors, and growth performance were recorded. At the conclusion of the feeding period, the steers were harvested at a commercial abattoir where carcass characteristics were measured. Data were analyzed as randomized complete block with diet as the fixed effect and block as the random effect using the PROC MIXED procedure of SAS. Linear and quadratic contrast were used to evaluate the effect of incremental levels of CM in the diets. Steer was the experimental unit for all analyses and α-value of 0.05 was used to declare significance. Trends were identified when $0.05 \leq P \leq 0.10$. A quadratic effect ($P < 0.01$) was observed in DMI where DMI increased with incremental levels of CM up to 10% in

the diets then decreased. Carinata meal had a quadratic effect on body weight on d 84 and 138 (P = 0.05 and 0.003, respectively). Body weights were lower in calves fed the control diet (CONT) and those fed the highest level of carinata meal (CM15). Carinata meal inclusion had a quadratic effect (P = 0.008) on overall average daily gain (ADG) in the finishing period. Calves fed lower levels of CM meal gained faster than those fed either 0 or 15%. Gain:feed was not affected by treatment (P = 0.11). There was a quadratic (P = 0.002) effect of CM inclusion on hot carcass weight (HCW). Weights increased from CONT to 5% CM meal (CM5) treatment, was consistent to 10% CM inclusion (CM10), and then decreased when CM was fed at 15% of the diet (CM15). There were no effects (P > 0.05) of treatment on REA or MARB. There was a quadratic effect (P = 0.005) of CM inclusion on backfat (BF) in which BF increased from CONT to CM10, then decreased with incremental levels of CM. There was a quadratic change observed on % KPH (P = 0.02) and YG (P = 0.009). These variables increased from CONT to CM10, then decreased with CM15 in the diets. Dry matter meal size (DMMS) tended to increase from CONT to CM5 and CM10 and decreased at CM15 (Quadratic, P = 0.09). Inter meal interval (IMI) increased linearly (P < 0.01) with incremental levels of CM in the diet. A linear decrease (P < 0.001) in meal duration (MD) was observed as the level of CM increased in the diet. A quadratic effect of treatment on as-fed meal size (MS; P = 0.04) was observed with increasing levels of CM in the diet. As-fed meal size increased from CONT to CM5, then decreased as the level of CM inclusion increased in the diet. This research suggests that CM may be able to serve as a functional source of crude protein in beef cattle finishing diets, but there may be an upper inclusion limit without reducing

performance. Further research needs to be completed to determine the value of CM as a protein supplement.

CHAPTER ONE

INTRODUCTION AND REVIEW OF LITERATURE

INTRODUCTION

Petroleum oil is an exhaustible resource, therefore, there is growing interest to find new alternatives to supply it. In addition, countries want to be independent of oil importation from foreign sources. On the other hand, the change in global climate is a concern and the development of other sources that produce less pollution in the environment, like plant oils, are developing to displace the use of petroleum (Drenth et al., 2014). The use of oilseed instead of petroleum has increased the supply of by-products available as feedstuffs (Carlsson, 2009). One crop currently being used for biofuels is *Brassica carinata* (*B. carinata*), which is grown in Ethiopia and also used for its leaves and oilseeds (Getinet et al., 1996). Carinata was incorporated into biofuel production within the USA and Canada for the oilseed. The carinata oil can be extracted from the seed to produce an industrial oil as biofuel; the carinata oil seed is not edible for human consumption (Atabani et al., 2013). The soils of the Northern plains of the USA and southern regions of Canada are ideal for growing *B. carinata* because it does not compete with other crops as corn, wheat and soybean (Marillia et al., 2014). Getinet et al. (1996) reported carinata meal (CM) with 10 to 11% crude fiber and crude protein ranging from 35 and 45% offering a new alternative as a protein supplement in cattle. Even though *B. carinata* is a good source of oil, their seeds contain naturally high amounts of glucosinolates (GLs) and erucic acid (EA). These compounds can affect the animal performance and health via metabolic interferences blocking the absorption of iodine by the thyroid gland and by their chemical properties (Makkar, 1993). Ruminants may tolerate GLs better than non-ruminants; however, current federal regulation (Food and Drug Administration) does not recommend feed meals containing more than 10% Gls in

the diet (Rodriguez-Hernandez and Anderson, 2017). The GLs and EA content of the diet may affect the feeding behavior and influence the consumption of feed. The presence of GLs causes a bitter flavor in the CM, and animals can decline to consume it and hence performance may be impacted (Tripathi and Mishra, 2007).

LITERATURE REVIEW

Agronomic Characteristics and Seed Quality of Carinata

The soils of the Northern plains of the USA and southern regions of Canada are ideal for growing *Brassica carinata* (Marillia et al., 2014). *Brassica carinata* is adaptable in these zones due to its tolerance for disease, drought, heat and pests (Teklewold and Becker, 2006). Field tests of *B. carinata* growth in South and North Dakota, Montana, Florida, Minnesota and Mississippi, found that yield response was dependent on climatic conditions such as temperature, humidity and seeding rate (Alberti, 2017). Originally, *B. carinata* was grown in Ethiopia and used for its leaves and oilseeds (Getinet et al., 1996). *Brassica carinata* is the seed of a mustard plant and this annual crop grows to a standing height from 30 to 200 cm. *Brassica carinata* has been grown within the USA and Canada for the oilseed which is used for biofuels. *Brassica carinata's* high oil content (24 to 36%) makes this plant a good source for making biofuel (Bailey et al., 2006).

The carinata oil can be extracted from the seed. The oil seed is not edible for human's consumption (Atabani et al., 2013). *Brassica carinata* is a source of oil for biofuel industry and is not planted on lands suitable for crops such as corn, wheat or soybean. Hence, *B. carinata* does not directly compete with land used to feed humans.

The growth characteristics of *B.carinata* allow this plant to be an economically feasible crop for producers. The extensive root system of *B. carinata* allows the plant to extract water from deep within the soil. Vegetation develops quickly and because this crop has secondary roots ramifications, *B. carinata* can capture more moisture from the soil. Thus, *B. carinata* produces between 1,100-1,500 kg of seeds per hectare (Falasca

and Ulberich, 2010). Brassica species, including the *B. carinata*, has many agronomical benefits in addition to its oilseed qualities. Due to its ability to tolerate frost, it can be planted in the winter season, which helps prevent erosion but does not negatively affect the soil. Furthermore, its genetic resistance to multiple weeds and diseases and the addition of biomass and carbon benefits the soil (Getinet et al., 1996). In Brookings, South Dakota, the best results were found with a seeding rate of 13.5 kg per ha which yielded 1,492 kg of seeds per ha and 517 kg of oil per ha (Alberti, 2017). The horticultural use of species from the Brassicaceae family is growing in different countries due to their benefits on human health. The seeds are rich in vitamin C, pro-vitamin A, high fiber content, sulfur compounds and antioxidants that can help in prevention of some types of cancers (Murillo and Mehta, 2001).

Brassica carinata plants are characterized as having high contents of oil and protein (Biosciences, 2015). Newkirk et al. (2003) reported that *B. carinata* seeds contain 33% oil, 34% protein, 8% oleic acid (total fatty acids basis), 42% erucic acid (EA) (total fatty acids basis), 16% linoleic acid and 13% linolenic acid (total fatty acids basis), and 120 µmol/g glucosinolates (GLs). Oil content levels between 24.7 to 35.5% for brown seed color lines and 37 to 51% for yellow seed color lines were reported (Getinet et al., 1996). Even though levels may vary by variety, the range in oil content shows the high amount of oil available that can be extracted. Other researchers (Getinet et al., 1996; Warwick et al., 2006) reported similar fatty acid characteristics to Newkirk et al. (2003) for individual *B. carinata* seeds. Mnzava and Olsson (1990) reported similar fatty acid concentrations as Newkirk et al. (2003): linoleic acid (19.9%), linolenic acid (10.8%), EA (40.6%) and oleic acid (13.0%).

The high oil content of *B. carinata* makes this variety attractive to the biodiesel industry. There is minimal effort required to produce the plant (Xin and Yu, 2013). Since *B.carinata* would not compete with existing food oil crops, the possibility of genetic modification options helps industries select *B. carinata* as a viable fuel source. According to Warwick et al. (2006), these attributes allow them to be planted and survive in many agricultural regions.

Protein Content

Brassica carinata, like other oilseed crops such as canola, can be processed for oil extraction. The two main procedures used by the industry are solvent and cold pressing extraction. Solvent extraction yields 95 to 99% of the oil contained in the seed through using a hexane solvent in combination with some form of mechanical extraction whereas cold pressing (mechanical) alone, yields 60 to 80% of the oil from the seeds (Atabani et al., 2013).

Newkirk et al. (2003) raised the question if the *B. carinata* by-products following oil removal is a viable feed for ruminants. The by-product of oil extraction of the *B. carinata* seed is referred to as carinata meal (CM) which has a high protein product with 50.4% DM (Table 1.1). Getinet et al. (1996) reported CM with 10 to 11% crude fiber and crude protein ranging from 35 and 45%. Additionally, the amino acid profile is well balanced (Table 1.2) for ruminant supplementation (Pedroche et al., 2007). Carinata meal protein content is reported to have 74.5% rumen degradable protein (RDP) and 25.5% rumen undegradable protein (RUP) indicating that its primary degradation would occur in the rumen (Xin and Yu, 2014). The physical characteristics of CM indicates a possible

use within animal production (Getinet et al., 1996); however, lack of information about the use of CM is limiting the incorporation into rations at the current time.

Contents of Glucosinalates and Erucic acid

Lardy and Kerley (1994) draws attention to the anti-nutritional factors of CM. Carinata seeds contain naturally high amounts of glucosinolates (GLs) and erucic acid (EA) which is also found in CM. By definition, anti-nutritional factors are compounds which affect the performance or animal's health via metabolic interference or by their chemical properties (Makkar, 1993). These substances (GLs and EA) can affect performance by interfering with the intake and utilization of feed (Bondi and Alumot, 1987).

Glucosinolates are secondary plant metabolites found in all Brassica species including carinata and are a natural defense system of the plants against some insects (Kliebenstein et al., 2005). The structure of GLs can vary based on climate, species, and agricultural practices. In addition, some species of plants can have a composition of a single GL, while others have more than 30 forms. There are more than 120 different GL configurations within the Brassicaceae family. These chemical configuration differences are responsible for different biochemical activities of the GLs (Mithen, 2001; Bellostas et al., 2007). Variations in the concentration of GLs are found within the same species and exists in different parts of the plant, including seeds, leaves, roots and stems. The concentration variation depends on nutrients, phenological status, maturity and stages of growth (Bellostas et al., 2007). Previously, Lardy and Kerley (1994) reported fluctuating concentrations of GLs and their profiles as the plant matures. Variation in GL concentration and profiles are influenced by external factors such as soil moisture,

nutrient availability and growing season. The concentrations of GLs (16 mg/g of DM) in CM may restrict its use as a feedstuff because of the bitter taste caused by glucosinolate degradation. The content of GLs in *B. carinata* seeds can range between 9 to 36.2 µmol of GLs per g of dry seed depending on the cultivars (Schuster and Friedt, 1998). Although ruminants may tolerate GLs better than non-ruminants, it is not recommended to feed meals containing more than 10% GLs in the diet, which is the current federal regulation according to the Food and Drug Administration and as recommended by the Agriculture and Agri-Food Canada (Personal communication Dr. Jill Anderson – 10/24/2016).

The meal components should contain less than 30 µmol of total GLs per g and less than 2.0% EA. Steers starting on feed can consume 10 to 15 µmol GLs per g of dry seed before exceeding the FDA guideline (≤ 10% of the ratio). However, no GLs are recommended for lactating cows and non-ruminants (Lawrence and Anderson, 2018). The most common symptoms of toxic levels of GLs are enlargement of thyroid gland associated with changes in thyroid metabolism and damage to the liver (Elfving, 1980). Glucosinolates are safe to the animal, however, the end product of the hydrolyzed GLs is potentially toxic. Glucosinolates are hydrolyzed by the enzyme myrosinase, present in *B. carinata* seeds and plants and in the animal's intestine. The enzymatic reaction results in formation of toxic components such as isothiocyanates, thiocyanates and nitriles, which are goitrogenic, nephrotoxic and hepatotoxic (Bennett et al., 2004; Cheng et al., 2004; Bell and Wagstaff, 2014).

Harmful toxic levels of GLs for humans and farm animals have been related to the compounds produced from the metabolism of GLs into thiocyanates, oxazolidinethiones

and nitriles. These three compounds restrict iodine uptake (thiocyanates) and the combination of the thyroid hormones T3 and T4 (oxazolidinethiones), causing hypothyroidism and an enlargement of the thyroid gland (Halkier and Gershenzon, 2006). These effects cannot be reversed with an increase in intake of iodine (Zukalová and Vasak, 2002).

Other adverse effects may include irritation and decrease of gastrointestinal tissue, underdeveloped growth, behavior changes, and disorientation causing unbalanced movements. Consequences of nitrile toxicity include retardment in growth, decline in milk production, reproduction fertility impairment, reduced offspring survival and lesions in the kidneys and liver (Mawson et al., 1994). By-products from degradation in the rumen of GLs are sinigrin and progoitrin, which can produce decrease feed intake, interfere with metabolism of the thyroid gland, and reduce fertility and reproductive performance in cattle (Schulmeister et al., 2016). The spicy flavor of *B. carinata* is due to the presence of GLs when sinigrin is most abundant. Bones and Rossiter (1996) suggested that sinigrin has positive benefits in humans against some types of cancer.

The presence of EA in seeds can range from 35 to 60% of the oil composition. One of the leading concerns related to EA ingestion in humans is myocardial lipidosis (Falasca and Ulberich, 2010). Foods with high amounts of EA are considered undesirable for human consumption because of myocardial lipidosis and heart lesions in rats in laboratory tests. Therefore, several countries have excluded EA in oils and fats to avoid health problems in humans. Lines of *B. carinata* with zero EA were developed (Getinet et al., 1994) to address this problem.

Fuel Characteristic

Petroleum oil is an exhaustible resource; therefore, there is growing interest to find new alternatives to supply it. In addition, countries want to be independent of oil importation from foreign sources. On the other hand, change in global climate is a concern and the development of other sources that produce less pollution in the environment, such as plant oils, are being developed to displace the use of petroleum (Drenth et al., 2014). The use of oilseed instead of petroleum has increased the supply of by-products available as feedstuffs (Carlsson, 2009).

The first flight of an aircraft completely powered with biofuel from *B. carinata* occurred in 2012. Before that, all the flights with biofuel were done with a mixed blend of 50% biofuel and 50% petroleum. The number of carbon particles emitted from *B. carinata* airplane fuel are less than the particles emitted by conventional jet fuel. *Brassica carinata* biofuel provides multiple benefits to the aerospace industry such as 1) increased distances and speed with *B. carinata* biofuel compared to fossil fuels, and 2) 80% reduction in greenhouse gas emission compared to fossil fuels (Cardone et al., 2002).

Animal Performance with Carinata Meal

Limited research using CM as a protein supplement has been conducted to evaluate performance of cattle. Leao Guidotti et al. (2018) compared carinata and canola meals at two inclusion levels (7.5 and 15% DM basis (DMB)) for a 97-day with backgrounding beef calves (n = 360). There was no differences between the protein supplements (CM and canola meal) on DMI, ADG or G:F. During the finishing period, crossbred steers (n = 250), were used to evaluate CM compared to canola meal, wheat

based dried distillers grains with solubles (DDGS) or combinations of CM and canola meal with WDDGS. These protein supplement treatments were CM alone (5% DMB), Canola meal (5.9% DMB) and WDG (6.2% DMB); and the combination of CM (2.8% DMB) + WDDGS (2.7% DMB); or Canola meal (3% DMB) + WDDGS (3% DMB). There were no differences between treatments ($P > 0.05$) for ADG, DMI or G:F (Leao Guidotti, 2018).

Schulmeister et al. (2016) tested ruminal fermentation and blood parameters in cannulated Angus crossbred steers (n = 8) receiving 1.39 kg/d CM pellets and compared with SBM, cottonseed meal, and DDGS. Based on this study, limited inclusion of CM was confirmed as a viable feed to be utilized as a protein supplement for beef cattle. In a 70-day trial using growing Angus heifers consuming Bermuda grass hay (control) or Bermuda grass hay plus CM (0.3% BW), heifers receiving the CM treatment gain 0.28 kg/d more than the heifer fed only Bermuda grass hay without altering thyroid hormone metabolism or age at puberty (Schulmeister et al., 2016). Based on these research studies, CM should be a viable protein supplement source for finishing and growing animals.

Feeding Behavior

The evaluation of feeding behavior is important to understand the mechanisms that regulate and control the intake of feed, how feed efficiency varies and to monitor the health status of the animals (Mendes et al., 2011). The environment, social factors and feed properties influence feeding behavior in animals. In the feed, flavor or taste is the most important property that affect the response of mammals to intake (Kyriazakis et al., 1999). Meal criteria estimates will depend on the type and weight of animals, diet, management system and competition for space.

For quantitative analysis, several terms need to be clarified to understand the behavior of animals when eating throughout the day. Bout is considered “a short period of intense activity of a specified kind”. Those bouts can be grouped together in a meal. We can define meal as “an act or the time of eating a portion of food to satisfy appetite”. The meal interval is the amount of time between two meals and is longer than the time the animal spends eating. The feeding rate is the total intake divided by the total time of the visit duration. There are different ways to record feeding bouts for further analysis. For example, feeding bouts can be recorded by direct visual observations, video film analysis, recording jaw movement, measuring feed disappearance, or visits recorded by computerized bunks (Tolkamp et al., 2000). Most of the feeding behavior data is based on recording the visits to the computerized bunk. The inter-meal interval (IMI) is the time period between meals (Mendes et al., 2011).

Meals are defined by 1) the amount of time to consider all the bouts as a meal and 2) what is the longest amount of time the animal spent eating that can still considered meal. Similarly, the minimum time between meals must be considered when defining a meal (Magni et al., 2009). Mendes et al. (2011) considered a 5-minute meal criterion for a high-grain diet. In another study, Gibb et al. (1998) defined a 20 minutes absence from the feeder as a new meal on steers. Tolkamp and Kyriazakis (1999b) mentioned that other authors used very different lengths from 2 to 45 minutes to consider an interval within the same meal.

The possibility that an animal will start eating again depends on the time since the last meal, which is related to the satiety of the animal. The amount of feed is a factor affected more by the feed intake than the time that the animal spends eating (Tolkamp

and Kyriazakis, 1999a). Looking to the organoleptic characteristics, taste or flavor are the most significant organoleptic characteristics that condition the animals to accept feed (Tolkamp et al., 1998). Different substances in the diet may affect the feeding behavior and influence the consumption of feed. The presence of GLs is important in vegetables from the Brassica family and due to their presence and bitter flavor in the CM, animals can decline to consume it. (Tripathi and Mishra, 2007). Rodriguez-Hernandez and Anderson (2018) found that a group of 24 Holstein heifers consuming 10% CM as DMB needed between one and two weeks to adapt to the flavor of CM. The two main compounds associated with the bitter taste are sinigrin and progoitrin, and become a problem when their concentrations are between 90 to 140 µmol per g (Lardy and Kerley, 1994).

Beyond palatability, the main concern with these compounds is their action to alter metabolism in the thyroid gland (Spiegel et al., 1993). These compounds bind with iodine and interfere with thyroid hormone synthesis (Zukalová and Vasak, 2002). By-products from degradation in the rumen of GLs like sinigrin and progoitrin decrease feed consumption, interfere with metabolism in the thyroid gland, and reduce fertility and reproductive performance.

To understand feeding behavior, researchers need to 1) record the times the animal visits the bunk and 2) record the time when the animal is not visiting the bunk. To establish a criterion, the feeding bouts are grouped into meals and the time between those meals recorded to set minimum time for a meal interval (González et al., 2008).

In the brain, the hypothalamus is the center that controls and integrates the signals for feeding behavior (Tolkamp and Kyriazakis, 1999b). Feed intake of a day is defined as

the number of daily meals, the amount of time and rate of those meals combined. Hicks et al. (1989) observed that 82% of steers (n = 93) spent between 2 and 10% of their time eating during a day. In other research, Hicks et al. (1990) found that animals in feedlots spend around 6–10% of the day eating. Friend and Polan (1974) reported that dairy cattle usually spend around 4 and 7 hours a day (16-30% of the day) eating. It is important to remember that cattle are social animals and they establish dominance at the bunk at feeding time (Friend and Polan, 1974). Social dominance correlates strongly positive with age, body size, horns and seniority in the herd (Grant and Albright, 1995). Average daily feed intake is associated with the number and size of the meals; ruminants are able to adjust their dry matter intake by varying the number of meals and meal size. Cattle have a highly repeatable pattern of feeding behavior and animals are stimulated with the presence of new fresh feed in the bunks (Hicks et al., 1989). Animal feeding behavior is important to identify the ways that feed intake is controlled (Bach et al., 2004), to analyze feed efficiency (Bingham et al., 2009), and to anticipate health problems in animals (Urton et al., 2005). Wolfger et al. (2015) analyzed the mean mealtime, frequency, and interval between meals and to find animals with Bovine Respiratory Disease in feedlots. Using feeding behavior, they were able to detect clinical problems seven days earlier than pen riders when the information was analyzed with electronic recording systems. Meal time duration and frequency of meals are associated with low risk of Bovine Respiratory Disease (Wolfger et al., 2015). In addition, Quimby et al. (2001) analyzed feeding behavior in lightweight steers received in a feedlot to find animals with Bovine Respiratory Disease. They found animals with signs of disease four days earlier than pen riders with a 90% efficacy (Quimby et al., 2001).

Insentec System

There are different ways to evaluate feeding behavior. Some of the traditional methods are direct observation by watching the animals or video. Another method is to measure the weight of feed disappearance from the bunks where they are eating. The development of electronic radio frequency identification (EID) technologies along with the Roughage Intake Control (RIC) system allowed the collection of data coming from large groups of animals with less labor compared with the traditional methods. The Insentec feeder's system manufactured by the Hokofarm Group (Voorsterweg 28 Marknesse 8316 PT, Netherland) utilizes an electronic identification system to collect feed disappearance information by individual animal. The RIC is part of a complete automated system that allows individuals to control feed intake of dairy and beef cattle.

The system records each time the animal visits bunks and the number of visits per day, when the animal starts and stops eating, and the weight of the bunks before and after the visit (feed disappearance) (Eradus and Jansen, 1999).

The Insentec data acquisition system records data every 10 seconds, which allows researchers to determine dry matter intake, number of meals, meal size, duration of feed intake, and time between meals by individual animal. Duration of feed intake is determined from time the Insentec recorded gate opens for a specific animal until the gate closes. When the animal arrives at one of the bunks, the following information is registered: animal identification, starting time when the animal initiates eating at the bunk, ending time when the animal leaves the bunk, duration of the intake, starting weight of the bunk before feed intake and finishing weight of the bunk after feed intake. The difference in weight determines the feed disappearance.

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Table 1.1. Chemical composition of carinata meal[a]

Nutrient	Concentration[b]
Dry matter, %	93.3
Crude protein, %	50.4
Rumen degradable protein, % of CP	74.5
Rumen undegradable protein, % of CP	25.5
Neutral detergent fiber, %	17.6
Acid detergent fiber, %	10.0
Ether extract, %	2.9

[a]Adapted from Xin and Yu (2013) and (2014).

[b]Dry matter basis.

Table 1.2. Amino acid profile of carinata meal[a]

Item	
Essential amino acids, % of crude protein	
Arginine	10.8
Leucine	6.8
Lysine	4.3
Valine	4.9
Methionine	1.8
Cysteine	2.0
Nonessential amino acids, % of crude protein	
Glutamic	20.7
Alanine	3.8
Aspartic acid	6.6
Proline	6.5

[a]Adapted from Pedroche et al. (2004).

CHAPTER 2

EFFECTS OF INCREASING DIETARY LEVELS OF CARINATA MEAL ON FEEDING BEHAVIOR, PERFORMANCE AND CARCASS CARACTERISTICS OF BEEF GROWING STEERS

INTRODUCTION

Brassica carinata is a non-food oil seed crop favorable to biofuel production and its oil has been utilized to produce airplane biofuel (Marilia et al, 2013). After oil extraction, a high protein meal is obtained. Getinet et al. (1996) reported that carinata meal (CM) contains 10 to 11% crude fiber and crude protein ranging from 35 and 45%. Even though *B. carinata* is a good source of oil and appears to be a viable protein source, their seeds contain naturally high amounts of glucosinolates (GLs) and erucic acid (EA). These compounds affect animal performance and animal health via hormone interference and by their chemical properties (Makkar, 1993). These substances (GLs and EA) present in the diet can affect the performance of the animal by interfering with the utilization of the feed (Bondi and Alumot, 1987). Current Food and Drug Administration regulations do not recommend feeding meals containing GLs at more than 10% of the diet (Dr. Jill Anderson – 10/24/2016). The GL and EA content of the diet may affect feeding behavior and influence consumption of the feed. The presence of GLs is important in vegetables from the Brassica family and due to their presence and bitter flavor in the CM, animals may decline to consume it and hence impact performance (Tripathi and Mishra, 2007). Our objective was to determine the effect of increasing levels of CM on the feeding behavior, animal performance, and carcass characteristics of growing beef cattle.

MATERIALS AND METHODS

Animals, Experimental Design, and Dietary Treatments

All experimental protocols and animal husbandry procedures were approved by the South Dakota State University Institutional Animal Care and Use Committee (number 16-084E). This experiment was conducted at the Cow Calf Research and Education Facility in Brookings, South Dakota, from January 31 to July 24, 2017.

Prior to the start of the experiment, 24 Simmental x Angus steers (244 ± 44 kg) were sourced from the South Dakota State University Cottonwood Range and Livestock Field Station. Upon arrival, the cattle were conditioned to the experimental facility from January 4 to January 30, 2017. Steers were vaccinated for Bovine Respiratory Disease (Bovi-Shield Gold, One Shot; Zoetis, Kalamazoo, NJ), Clostridium Perfringes types C & D and tetanus toxoid (Professional Biological Company, Denver, CO) and received an injectable anthelmintic dose (Ivomec, Merial, Duluth, GA). Animals were also tagged with radio frequency identification tags (Allflex USA Inc, Dallas-Fort Worth, TX). During conditioning to the experimental facility, steers were trained to recognize how to obtain feed from the Insentec RIC feeding system (Hokofarm, Marknesse, the Netherlands). All animals had *ad libitum* access to a total mixed ration (TMR) which consisted of 24.3% high-moisture corn, 71.1% corn silage, 1.2% mineral supplement, and 3.3% liquid supplement. The steers were housed together in one partially-covered pen (18 × 91 m). The pen consisted of a concrete (18 x 12 m) portion under-roof and a bare ground (18 x 79 m) portion. The pen was not bedded to avoid consumption of the bedding. Twelve Insentec RIC feeders with a capacity of 160 L (1.0 × 0.68 × 0.82 m) were located adjoining the concrete portion of the pen. During the conditioning period,

the diet was placed into the feed bunks with all the gates down so that the steers would have unrestricted access to the feed. After every four days, the gate height was increased by 3.8 cm during the conditioning period. The gates were opened and closed so that steers are familiar with the noise of the gates when obtaining feed. During this period of time, all of the steers had access to all 12 of the feeders. After the conditioning, the steers were limited to their individual assigned feeders. Each individual feed bunk was assigned to two steers. Feed was delivered as a TMR once daily at 1000 hours. Water was provided *ad libitum* through three waterers during the entire experimental period.

The Insentec RIC system records meal size, meal time and meal intervals. These data were used to calculate individual feed intake and feeding behavior. Each animal was identified with an electronic ID tag (transponder) with a unique number. That number is recorded into the computer program of the RIC system. Once the animal was introduced into the system, the next step was to assign the corresponding diet to the bunk where the animal is going to obtain feed.

The system consists of a bunk assembled on two load cells that measure the weight of the bunk with the feed and registers the differences in the weight of the bunk before and after feed disappearance. The bunks have an antenna linked to the computer system that captures the signal from the electronic tag and detects the presence of the animal at the feed bunk. The bunk has a pneumatic sliding gate that raises and lowers, and the eating pattern of an animal was controlled by closing and opening the gate. The electronic system estimates individual feed intake by continuously weighing feed disappearance during each bunk visit. We are assuming feed disappearance is directly proportional to feed intake.

Additionally, the animal needs to block the signal from a photocell to allow the gates to lower and the design of the bunks and gates allow only one animal to enter at the feed bunk at a time. While the animal was eating, the infrared sensors keep the gate lowered. When the animal finished eating and moved out of the bunk, the gate raises and did not reopen for seven seconds after the visit.

Data acquisition software (RIC-Management Windows version RW: 1.7) records all the feeding behavior and feed disappearance data. The computer program checks for new records every ten seconds. At the start of the adaptation period, steers were weighed on two consecutive days on January 31 and February 1, 2017. The steers were blocked by BW at the beginning of the adaptation period and randomly assigned to an Insentec feeder so that two steers were assigned to each feeder, and six animals were assigned per treatment. The adaptation period consisted of five steps and was implemented from January 31 until March 7, 2017. The ingredient composition as percent of DM of the four treatment diets for each of the five steps of the adaptation to the treatment diets are described in Table 2.1. Within the four corn-based treatment diets, carinata meal replaced HMC at 0 (control), 5, 10, or 15%. Steers were initially offered the diet at 1.6% of their BW daily, then the ration was increased until steers reached *ad libitum* intake of the step 5 finishing diet (Table 2.2). On March 8, 2017, the steers were implanted with anabolic and estrogenic steroids (200 mg trembolone acetate and 40 mg estradiol; Revalor-XS, Merck Animal Health) and the feeding behavior experiment started.

Body Weight and Feed Intake Measurements

Steers were weighed individually every week before the morning feeding (1000 hours) from January 4 through February 28, 2017. The steers were weighed during the finishing portion of the trial every 28 days on March 8 and 9, April 4, May 2, May 30, two consecutive days on June 25 and 26 and two consecutive days on July 23 and 24, 2017. One data point from the control treatment was missing for May 2 day due scale malfunction.

Every day at 0900 hours, feed calls were completed and assigned a scale of 0 to 3 (Table 2.3). Only after three consecutive days of a zero score, diets were increased 3% on a DM basis. No changes were made if the bunk had a different score. Diets were mixed in a one cubic meter stationary mixer (Davis Precision Horizontal Mixer, Model HD-5, H. C. Davis and Sons Manufacturing Co., Inc., Bonner Springs, KS) with the following sequence: 1) high-moisture corn, 2) mineral supplement (Table 2.4), 3) CM pellets (Table 2.5), 4) liquid supplement (Table 2.6) and 5) corn silage. Diets were mixed in order of increasing level of CM starting with the control diet. Every day the mixer was brushed at the end of the feeding sequence, so the mixer was clean and ready to use the next morning.

Feed was delivered using a Valmetal Supercart HT 542 (Valmetal, Tomah, WI). With one diet at a time, starting with the CONT and finishing with the CM15, the sequence was completed within 90 minutes. Prior to feeding, the animals were removed from the pen's concrete area until all of the feed had been delivered. This step ensured that all animals had access to the bunks for the same amount of time. Animals were observed at least twice daily to detect abnormal behavior, diseases or injuries.

Measurements of Feeding Behavior

For quantitative analysis, several terms need to be clarified to understand the behavior of the animals when eating throughout the day. Bout was defined as a short period of intense activity of a specified kind. In our experiment was all the feed intake registered in a period of time no longer than 30 minutes. Bouts can be grouped in a meal. Meal was defined as the amount of feed that the steer ate to satisfy their appetite. The meal interval was the amount of time between two consecutive meals. The feeding rate was the total intake divided by the total time of the visit duration. Bouts can be grouped in a meal where they are separated by different amounts of time, short or long periods. Parameters within bouts must are defined by 1) the amount of time to consider the bouts as a meal and 2) what is the longest amount of time that can still considered meal. Based on Tolkamp and I. Kyriazakis (1999), in this project 30 minutes between registered intakes was selected as the minimum time to consider a different meal. If a given steer visited the bunk after 30 minutes since the last visit, a new meal was identified. The feeding behavioral activities for each steer were continuously recorded for 24 h per day for a period of 138 consecutive days. Behavior measurements included: 1) number of meals per day (NOM); 2) inter-meal interval (IMI); 3) meal size measured as DMI intake (DMMS); 4) Total dry matter intake (DMI); and 5) meal duration (MD) (Table 2.7).

Feed Analysis

Feed samples were collected once per week and placed in a plastic bag and frozen at -20ºC prior to analysis. All the feed samples were analyzed in duplicate. Dry matter was determined by oven drying samples 105°C for 24 h. Diet samples were ground to pass through a 1-mm screen (Thomas-Wiley Mill Model 4, Thomas Scientific USA,

Swedesboro, NJ). Petroleum ether was used in an EE Ankom XT 10 Extractor (Ankom Technology, Macedon, NY) to determine ether extract. Nitrogen content was analyzed by the Dumas procedure (method no. 968.06; AOAC, 2016; rapid Max N exceed; Elementar, Mt Laurel, NJ). Neutral detergent fiber (NDF) was measured as described by Van Soest et al. (1991) and acid detergent fiber (ADF) was measured non sequential to NDF (Van Soest et al., 1991). The ash content was determined by burning the sample in an oven at 550 ºC for 24 h. The organic matter was determined by correction method of DM with ash content.

Statistical Analysis

Growth performance: body weight, average daily gain (ADG), gain to feed (G:F); carcass characteristics: hot carcass weight (HCW), rib eye area (REA), marbling (MARB), back fat (BF), % kidney pelvic hip fat (KPH), yield grade (YG); and feeding behavior: dry matter intake (DMI), dry matter meal size (DMMS), number of meals (NOM), inter-meal interval (IMI), meal duration (MD), meal size (MS) were analyzed with diet as the fixed effect and group (i.e., block) as the random effect using the PROC MIXED procedure of SAS (Version 9.3; SAS Inst. Inc., Cary, NC). Body weight and ADG were analyzed as a repeated measure using analysis of variance with fixed effects of treatment (carinata meal levels) and treatment x month interaction and random effect of month nested within animal. This analysis was completed using the nlme package in R software. There was a significant treatment-by-month interactions ($P < 0.05$) for body weight. Thus, each weigh date was analyzed separately to determine if carinata meal inclusion affected body weight and ADG. Linear and quadratic contrast were used to evaluate the effect of incremental levels of CM in the diets. Steer was the experimental

unit for all analyses, an α-value of 0.05 was used to declare significance, and trends were discussed as $0.05 \leq P \leq 0.10$.

RESULTS

Growth and Feed Efficiency of CM levels

There were no linear or quadratic effects of CM levels on BW during the adaptation phase (Table 2.8). There was no linear or quadratic effect of treatment on BW on d 0, 28 and 56 of the finishing phase. Beginning on day 84, treatment had a quadratic ($P = 0.05$) effect on BW. Calves fed carinata meal all had greater BW than CONT calves, but BW decreased with increasing levels of carinata meal. On day 138 there was a quadratic effect ($P = 0.003$) of treatment on BW with a similar pattern as was observed on d 84. Treatment had a quadratic relationship to ADG from d 0 – 28 ($P = 0.026$), d 29 – 56 ($P = 0.007$) and through the entire finishing period d 0 – 138 ($P \leq 0.001$). A quadratic tendency ($P = 0.06$) was observed from d 85 – 138. Average daily gain increased from CONT to CM5 treatment and decreased started at CM10 treatment and then decreased for CM15. No linear and quadratic effect across treatments were observed on gain:feed with incremental levels of CM in the diet (Table 2.9).

Carcass Data

Treatment had a quadratic effect ($P = 0.002$) on HCW. Hot carcass weight increased from CONT to CM5 treatment, then decreased at greater inclusion of CM in the diets. There were no linear or quadratic effects ($P > 0.05$) of treatment on REA and MARB. However, there was a quadratic tendency on MARB ($P = 0.09$) where marbling

scores increased with addition of carinata meal-fed cattle relative to CONT but decreasing with increasing dietary levels of carinata meal. There was a quadratic effect ($P = 0.005$) of treatment on BF. Back fat increased from CONT to CM10, then decreased with incremental levels of CM. There was a quadratic effect ($P \leq 0.02$) observed of treatment on KPH and YG. Both variables increased from CONT to CM10, and then decreased with incremental levels of CM in the diets (Table 2.10).

Feeding behavior during finishing diets

The effects of inclusion level of CM treatments on feeding behavior are presented in Table 2.11. Treatment had a quadratic effect on DMI ($P < 0.01$) which increased from CONT to CM10 and then decreased with the CM15 treatment. There was a quadratic tendency of CM treatment on DM meal size ($P = 0.09$) in which DMMS increased to CM5 and CM10 and then decreased with next incremental levels of CM in the diet. The DMMS decreased at CM15 but was higher than CONT. There were no effects of increasing CM level in the diet on NOM ($P \geq 0.20$). Treatment had a linear effect on IMI ($P < 0.01$) with increasing levels of CM in the diet. A linear decrease ($P < 0.001$) was observed on MD as the level of CM inclusion increased in the diet. A quadratic effect of treatment on as-fed MS ($P < 0.04$) was observed with incremental levels of CM in the diet. The as-fed MS increased from CONT to CM5 and then decreased as the level of CM inclusion increased in the diet.

DISCUSSION

Animal Performance

There is limited information on animal performance with CM inclusion in the diet. Leao Guidotti (2018) reported lower ADG (1.08 kg/d) for steers fed diets containing 7.5% and ADG (1.10 kg/day) for 15% CM compared to the steers on this project (ADG 1.5 to 1.7 kg/d). This could be explained by the other diet ingredients or genetics. Diets used by Leao Guidotti (2018) were rolled barley, alfalfa hay, barley silage and a formulated supplement, which would contain less energy compared to the diets used in this project. However, the low performance of the CONT compared with CM5, CM10 and CM15 could be explained by the low % of protein in the diet of the CONT group. This difference in protein was an unintentional error due to the lack of inclusion of urea in the CONT group to ensure all groups were fed the same protein content. Replacement heifers fed Bahiagrass and CM at 0.3% of BW had ADG of 0.48 kg compared to heifers receiving only *ad libitum* Bahiagrass hay (0.28 kg; Schulmeister et al., 2015). A 0.3% of BW CM inclusion would be approximately 1.7 kg/d of CM which is higher than the 15% inclusion used in this project.

Carcass Data

There is limited information on carcass characteristics with growing/finishing cattle fed with CM. McKinnon et al. (2012) reported no differences in rump fat thickness in steers fed control or 10% CM diets. Leao Guidotti (2018) found no differences on MARB and HCW in steers fed 10% CM or steers fed 20% canola meal.

Feeding Behavior

The lowest DMI was found in the control group while DMI increased to CM10 and decreased at CM15. Montanholi et al. (2010) reported an average DMI of 8.97 kg with steers (313 kg) on a diet consisting of high-moisture corn 80% DM without CM, similar to the 8.86 kg DMI of CM10. Within the current study, as the CM increased in the diet to CM15 the DMI declined, possibly due to the bitter taste of the diet. In a study with a GrowSafe system, a group of steers (mean BW = 412 kg) had a DMI of 11.5 kg/d on a steam rolled barley grain and barley silage diet (Gibb et al., 1998). Additionally, Swanson et al. (2014) reported DMI from 11.0 to 12.1 kg/d steers (345 kg) on the dry-rolled corn diet with increasing levels of dried corn distillers' grains plus solubles. Our research showed slightly less DMI; however, this discrepancy may be explained by the diet ingredients and size of animals.

No differences in DMMS suggests that the anti-nutritional factors (glucosinolates and erucic acids) did not influence the meal size. The average meal size was 1.46 kg, which was slightly higher than the 1 kg reported by Montanholi (2010) where the diets did not contain CM. Thus, CM inclusion did not affect meal size. However, the quadratic tendency of treatments on DMMS, where DMMS increased from control to CM5 and CM10 then decreased with 15% inclusion of CM could be explained by the bitter taste of the CM. Lardy and Kerley (1994) drew attention to the anti-nutritional factors of CM. Carinata seeds contain naturally high amounts of glucosinolates (GLs) and erucic acid (EA) which are also found in the CM. By definition, anti-nutritional factors are compounds which affect animal performance or health via metabolic interferences with thyroid hormone or by their chemical properties (Makkar, 1993). The presence and

concentration of GLs in the feed can inhibit the intake of the diet affecting the performance of the animals. These substances (GLs and EA) present in the diet can affect, performance interfering with the utilization of the feed (Bondi and Alumot, 1987). The higher % of CM (15% inclusion) could cause the feed to taste bitter.

Within the current project, steers averaged 5.9 meals per day, which is lower than reported by others e.g. (Montaholi et al., 2010; Vasilatos and Wangsness (1980) and Swanson et al., 2014). Swanson et al. (2014) reported meals at 8.0 meals per d with yearling steers. Montanholi et al. (2010) reported even a higher number of meals per day at 9.2 with Angus steers. When lactating dairy cows were fed on corn silage diet, the average number of meals per day increased to 12.1 (Vasilatos and Wangsness, 1980).

The steers on the CONT diet had the least amount of time between meals compared with all the CM treatments (CM5, CM10 and CM15). As the percentage of CM increased in the diet the interval between meals was longer. The CM10 and CM15 had the longest interval. Two factors that could explain the interval between meals are satiety and the aversion of taste in the feed. The possibility that an animal will start eating again depends on the time since the last meal, which is explained by the satiety of the animal. Tolkamp and Kyriazakis (1999) indicated that the feed intake is a factor that affected satiety more than the time that the animal spent eating. Additionally, the organoleptic characteristics of a feed (taste or flavor) are the most important characteristics that determine whether the animals accept the feed (Tolkamp et al., 1998).

Different substances in the diet may affect feeding behavior and influence the consumption of feed. The presence of GLs in vegetables from the Brassica family, due to their bitter flavor in the CM, can reduce the animal's desire to consume the feed (Tripathi

and Mishra, 2007). Rodriguez-Hernandez and Anderson (2018) found that Holstein heifers needed between 1 and 2 weeks to adapt to the flavor of CM. The bitter taste in CM containing diets could affect the consumption of the feed making the interval longer between meals. In the current study, steers were on CM at the specific rate for 35 days prior to collecting the feeding behavior data so should have adapted to the CM in the diet. Unless 15% CM was too high for the animals to adapt to.

The time spent eating the meal (MD) was greater for the control group. As the percent of CM increased in the diet, the MD decreased. The bitter taste in CM containing diets may affected intake and produced aversion to the TMR, resulting in a shorter MD. Montanholi et al. (2010) reported an average MD of 15.06 min in finishing steers and Vasilatos and Wangsness (1980) reported a 20.9 min MD with dairy cows. Hicks et al. (1990) showed that animals in feedlots spent 6–10% of the day eating, however, steers in the current study spent approximately 13% of their day eating. Gibb et al. (1998) found that steers on the GrowSafe system spent 33.6 min per meal eating, which was similar to our results, but with higher number of meals per day (8.4 NOM) than our study. With the same GrowSafe system, Mendes et al. (2011) with heifers on a diet without CM and consisted of 73.7% dry rolled corn, had MD results of 119.3 min/d.

In the current study, average MS was 2.54 kg for the treatments. There was a quadratic effect of treatment on MS. Meal size increased from control to CM5 and CM10 and decreased at CM15 to a similar level of the CONT (Table 2.7). Montanholi et al. (2010) reported lower meal sizes (1 kg) but with more NOM (9.21) on finishing steers compared to the 2.54 kg MS and 5.8 to 6.1 NOM found here.

IMPLICATIONS

The biofuel production from *B. Carinata* seeds leave a large amount of residue high in protein known as CM. The fuel produces fewer numbers of particles of carbon and reduces the contamination in the enviroment.

The use of CM opens an opportunity for the producer to have a new source to use as a protein supplement in beef cattle to replace conventional products like soybean meal, or sunflower meal (SFM).

The protein supplements are an important component of the diet in beef cattle and their use will depend on their cost, safety and performance of animals on diets with these supplements. The cost of CM need to be lower than other protein supplements used to stimulate producers to introduce CM in diets. Studies will be necessary to understand and to measure the presence of EA to be sure that the meat is safe for the consumer. Due to its bitter taste and the presence of GLs, the increasing amounts of CM could diminish feed consumption which may impact performance. If CM does not affect performance, producers can use CM as another alternative for protein supplementation.

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Table 2.1. Diet formulations during the adaptation phase

Control	Step 1	Step 2	Step 3	Step 4	Step 5
Item			% of diet DM		
High-moisture corn	38.9	38.9	48.9	58.9	68.9
Corn silage	53.3	53.3	43.3	33.3	23.3
Carinata meal	0	0	0	0	0
Mineral supplement	2.8	2.8	2.8	2.8	2.8
Liquid supplement	5	5	5	5	5

5% Carinata	Step 1	Step 2	Step 3	Step 4	Step 5
Item			% of diet DM		
High-moisture corn	33.9	33.9	43.9	53.9	63.9
Corn silage	53.3	53.3	43.3	33.3	23.3
Carinata meal	5	5	5	5	5
Mineral supplement	2.8	2.8	2.8	2.8	2.8
Liquid supplement	5	5	5	5	5

10% Carinata	Step 1	Step 2	Step 3	Step 4	Step 5
Item			% of diet DM		
High-moisture corn	28.9	28.9	38.9	48.9	58.9
Corn silage	53.3	53.3	43.3	33.3	23.3
Carinata meal	10	10	10	10	10
Mineral supplement	2.8	2.8	2.8	2.8	2.8
Liquid supplement	5	5	5	5	5

15% Carinata	Step 1	Step 2	Step 3	Step 4	Step 5
Item			% of diet DM		
High-moisture corn	33.9	23.9	33.9	43.9	53.9
Corn silage	43.3	53.3	43.3	33.3	23.3
Carinata meal	15	15	15	15	15
Mineral supplement	2.8	2.8	2.8	2.8	2.8
Liquid supplement	5	5	5	5	5

Table 2.2. Diet composition and nutrient analysis of finishing diets

	Carinata meal inclusion[1], % of DM			
Item[a]	0	5	10	15
	Diet composition, % of diet DM			
High-moisture corn	68.9	63.9	58.9	53.9
Corn silage	23.3	23.3	23.3	23.3
Carinata meal	0.0	5.0	10.0	15.0
Mineral supplement	2.8	2.8	2.8	2.8
Liquid supplement	5.0	5.0	5.0	5.0
	Nutrient analysis, % of diet DM			
Dry matter	57.2 ± 0.57	56.32 ± 0.34	57.82 ± 0.45	58.54 ± 0.64
Organic matter	95.0 ± 0.05	94.65 ± 0.07	94.25 ± 0.13	93.61 ± 0.17
Crude protein	8.64 ± 0.06	10.36 ± 0.09	11.97 ± 0.28	14.35 ± 0.21
Neutral detergent fiber	11.2 ± 0.40	12.69 ± 0.24	15.89 ± 1.13	13.52 ± 0.46
Acid detergent fiber	6.96 ± 0.22	6.64 ± 0.14	7.72 ± 0.27	7.66 ± 0.37
Ether extract	5.09 ± 0.17	2.88 ± 0.32	3.73 ± 0.23	3.38 ± 0.21
NEm, Mcal/kg[2]	2.00	1.96	1.94	1.91
NEg, Mcal/kg[2]	1.35	1.33	1.30	1.28

[a] % DM inclusion

[1] Formulated inclusion

[2] NEm = net energy for maintenance; NEg = net energy for gain; values predicted from tabular values, except for CM, which was 1.67 Mcal/kg NEm and 1.06 Mcal/kg for NEg

Table 2.3. Bunk scoring system used

Score	Description
0	No feed remaining in the bunk
0.5	Scattered feed present. Most of bottom of the bunk exposed
1	Thin uniform layer of feed across bottom of the bunk.
2	25%-75% of previous feed delivery remaining
3	Feed untouched

Table 2.4. Mineral supplement composition

Item	% of DM
Sodium chloride	84
Vitamin A	0.27
Vitamin D	0.009
Vitamin E	1.66
Zn sulfate	2.81
Co sulfate	0.10
EDDI[1]	0.454
Cu sulfate	0.132
Fe sulfate	8.321
Mn sulfate	2.08
Se premix	0.07

[1]Ethylenediamine dihydrioidide

Table 2.5. Nutrient composition of carinata meal

Item	Value
Moisture, %	7.48
Crude protein, %	50.22
Gross energy, kcal/kg	4.853
Ether extract, %	0.88
Starch, %	8.70
Neutral detergent fiber, %	26.79
Acid detergent fiber, %	15.37
Indispensable AA, %	
Arg	3.55
His	1.30
Ile	2.07
Leu	3.45
Lys	1.82
Met	0.96
Phe	2.04
Thr	1.89
Trp	0.64
Val	2.51
Dispensable AA, %	
Ala	2.09
Asp	3.43
Cys	1.35
Glu	9.07
Gly	2.43
Pro	3.01
Ser	1.61
Tyr	1.33

Table 2.6. Liquid supplement composition

Item	
Dry Matter, %	58
Crude protein, %	20.17
NPN protein, %	14.63
Fat, %	1.12
Fiber, %	0.40
Ca, %	0.6
P, %	0.24
Salt, %	4
K, %	2.09
S, %	0.32
Monensin, g/kg	0.488
Tylosin, g/kg	0.133

Table 2.7. Description of recorded behavioral activities of the steers

Behavior	Description of behavior
Number of meals per day	The frequency by which each steer visited the bunk, grouped in visits not spaced for more than 30 minutes
Inter meal interval	The amount of time between two meals
Meal size measure as dry matter intake	The amount of feed that each steer consumes measured in kg of dry matter in each meal
Total dry matter intake	The average of the sum of dry matter intake of all meals in the day
Meal duration	The amount of time that a steer spent eating each meal with all the visits grouped
Meal size	The quantity as feed consumed by a steer during a meal

Table 2.8. Influence of carinata meal inclusion on body weight during adaptation period

	Carinata meal inclusion, % DM					*P*-values	
	0	5	10	15	SEM	Linear	Quadratic
Day 0 BW, kg	287	291	287	288	11.07	0.98	0.91
Day 7 BW, kg	283	289	285	285	10.50	0.97	0.79
Day 14 BW, kg	292	297	293	298	10.62	0.76	0.99
Day 21 BW, kg	293	302	299	299	10.70	0.78	0.74
Day 28 BW, kg	302	311	309	315	11.19	0.46	0.92
Day 35 BW, kg	308	325	327	329	12.13	0.25	0.58
Final BW, kg	320	344	341	345	13.05	0.24	0.47

Table 2.9. Influence of carinata meal on body weight, average daily gain and gain:feed ratio during the finishing period

	Carinata meal inclusion level, % of diet DM					*P*-value	
Item	0	5	10	15	SEM	Linear	Quadratic
Body weight, kg							
Day 0	320	344	341	345	13.05	0.24	0.47
Day 28	363	401	401	403	14.87	0.09	0.24
Day 56	423	449	450	437	13.89	0.48	0.13
Day 84	451	512	505	496	16.67	0.11	0.05
Day 138	495	580	568	557	13.89	0.01	0.003
Average daily gain, kg/d							
Days 0-28	1.51	2.04	2.15	2.07	0.12	0.005	0.026
Days 29-56	1.50	1.71	1.76	1.20	0.14	0.15	0.007
Days 57-84	1.75	2.23	1.96	2.10	0.15	0.29	0.30
Days 85-138	1.00	1.69	1.46	1.51	0.16	0.09	0.06
Overall	1.27	1.71	1.64	1.54	0.07	0.03	0.0008
Gain:feed (kg:kg)	0.18	0.21	0.19	0.19	0.01	0.61	0.11

Table 2.10. Influence of carinata meal on carcass characteristics

	Carinata meal inclusion level, % of diet DM					*P*-value	
Item[a]	0	5	10	15	SEM	Linear	Quadratic
HCW, kg	286.1	338.4	329.6	320.2	8.52	0.02	0.002
REA, cm^2	73.01	79.09	74.90	75.79	3.19	0.77	0.42
MARB[b]	434.33	533.67	507.08	468.33	38.69	0.67	0.09
BF, cm	0.77	1.07	1.20	0.89	0.10	0.28	0.005
KPH, %	1.95	2.04	2.09	1.75	0.08	0.16	0.02
YG	2.42	2.88	3.15	2.65	0.16	0.21	0.009

[a]HCW = Hot carcass weight; REA = ribeye area; MARB = marbling; BF = backfat; KPH = kidney, pelvic, and heart fat; YG = USDA Yield grade

[b]400 = $small^0$ marbling

Table 2.11. Influence of carinata meal on feeding behavior

	Carinata meal inclusion, % of diet DM					*P*-value	
Item	0	5	10	15	SEM	Linear	Quadratic
Dry matter intake, kg	7.22	8.27	8.86	8.34	0.32	<0.01	<0.01
Meal size, kg DM	1.36	1.53	1.54	1.41	0.12	0.65	0.09
Number of meals per day	5.8	5.8	6.0	6.1	0.27	0.20	0.74
Inter meal interval, min	137	148	158	160	6.8	<0.01	0.40
Meal duration, min	38	33	29	25	1.8	< 0.001	0.87
Meal size, kg (as-fed)	2.36	2.74	2.66	2.39	0.22	0.97	0.04