

AN ABSTRACT OF THE THESIS OF

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Title: Puberty Development and Reproductive Performance in Beef Heifers Fed Rations Supplemented with Oregon By-Product Feeds

Abstract approved:

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In the majority of management scenarios, it is imperative that beef replacement heifers calve at two years of age. In order to achieve this goal, yearling heifers should reach 60 to 65% of their mature body weight by 13 months of age. Feed costs represent 75 to 80% of the total costs incurred by a beef producer in the development of replacement heifers. At current beef prices, it takes at least three live calves before the heifer development period is paid.

Feed costs have become more problematic and volatile in recent years. Increasing pressure for the use of grains in brewing and for ethanol production has inflated feed prices. Demand for grain has also resulted in more ground being taken

out of forage production which has resulted in much higher hay prices. However, the increased use of feedstuffs by fermentation industries results in by-product feeds that can be utilized best by beef cattle. Utilization of these by-product feedstuffs by cattle not only results in cheaper feed, and therefore production costs, but also enhances the sustainability of the fermentation industry.

The objective of this research was to evaluate puberty onset and subsequent reproductive performance in heifers fed a traditional ration with grass hay to rations in which grass hay was substituted with either grass-seed straw or a grass seed straw-brewer's grain silage.

Eighteen heifers (initial body weight = 561 ± 11.4 lbs and age = 278 ± 2.4 d) were randomly assigned to one of three treatment groups: grass hay (HAY), grass seed straw (STRAW), or grass seed straw-brewer's grain silage (SILAGE). Heifers were individually fed twice daily using Calan gates for 22 weeks. Heifers were weighed and 10-ml blood samples were recovered weekly. Plasma was recovered by centrifugation and stored at -20° C until analyzed for progesterone and Anti-Mullerian Hormone (AMH) concentrations. Puberty onset was defined as plasma progesterone exceeding 1 ng/ml. At week 21, heifers were estrous-synchronized using a CIDR-Select Synch protocol. Heifers displaying estrus were inseminated 12 h after onset with one straw of frozen semen. Heifers not displaying estrus were injected with $\text{PGF}_{2\alpha}$ 10 d after the initial $\text{PGF}_{2\alpha}$ injection in the CIDR-Select Synch protocol and subsequently observed for estrus and inseminated as described.

Mean ages and weights of heifers were similar ($P>0.10$) across all treatments at the start of the feeding period. Heifer ages at puberty did not differ ($P>0.10$) due to treatment. Average daily gain of heifers during the feeding trial fed SILAGE were lower ($P<0.0005$) than heifers fed either HAY or STRAW, However, no differences ($p>0.10$) were found in body weight at puberty onset. However, body weights of heifers fed SILAGE were lower ($P<0.05$) than heifers fed either HAY or STRAW at the starts of the breeding and calving seasons. No differences ($P>0.10$) in services per conception, calving ease scores, calf vigor scores, or calf birth weights were observed between treatments. These results suggest that heifers fed the less expensive, by-product STRAW ration have weight gain and reproductive performance similar to heifers fed a traditional HAY ration. Although heifers fed the SILAGE diet had lighter body weights, a negative impact on reproductive measurements was not observed, suggesting the ration was adequate to support reproductive performance similar to a traditional HAY ration.

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Puberty Development and Reproductive Performance in Beef Heifers Fed Rations
Supplemented with Oregon By-Product Feeds

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Keely E. Oswald, Author

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INTRODUCTION

The beef industry in the United States plays an important role in the economy of our country as well as providing a safe and wholesome protein supply for American consumers. In 2007, the U.S. had more than 32.8 million beef cows and over 600,000 of those were in Oregon (United States Department of Agriculture, National Agricultural Statistics Service). Cattle and calves are the second most valuable agriculture product in Oregon and contributed more than \$800 million in sales to Oregon's economy in 2007 (United States Department of Agriculture, National Agricultural Statistics Service).

The goal of a successful cow-calf operation is to economically produce one healthy, productive calf per cow each year. The management of beef females in the cow-calf herd plays a huge role in the success of a beef operation. The longevity of the cow is a chief concern for productivity on a cow-calf operation. Failure to become pregnant is the primary reason a beef cow is culled from an operation (Cushman, et al., 2009).

To provide a steady supply of beef to the US, heifers play an integral part in sustaining herd size. Replacement heifers are necessary to replace cull cows, maintain cow numbers, and to improve the genetics of the herd (Bagley, 1993). The most expensive and, arguably, the most critical time in a beef female's life is the heifer development period. The heifer development period can be defined as the time from a heifer's birth until she calves for the first time at approximately two years of age.

Management decisions made during this time can have lifelong effects on the efficiency of the beef female.

Heifers must reach puberty by fifteen months of age if they are to conceive and calve by 24 months old. However, up to 35% of heifers fail to reach puberty by the 15 month old goal (Patterson, et al., 1992). Heifers that have their first calf as a two year old produce more calves in their lifetimes than those who first calve at three years of age (Martin, et al., 1992; Patterson, et al., 1992). Future reproductive performance is dependent on the timing of a heifer's first calf. Heifers who conceive early in their first breeding season have greater lifetime productivity than heifers who conceive later in the breeding season (Martin, et al., 1992; Patterson, et al., 1992). Since the breeding season remains constant and is limited to a restricted time period, females who have more than 365 days between calves were eventually unable to become pregnant in this restricted breeding season (Patterson, et al., 1992).

There is pressure for heifers to calve 1-2 estrous cycles ahead of the cow herd (Larson, 2007). Because heifers typically require more assistance during calving, they are bred to calve prior to the cow herd. This allows producers to concentrate labor on assisting heifers (Larson, 2007). Calving early in the calving season also allows females more time for uterine involution and resumption of normal estrous cycles prior to rebreeding (Larson, 2007) and results in a higher lifetime calf crop (Patterson et al., 1992). Females who calve earlier in the calving season also wean heavier calves (Patterson et al., 1992). Therefore, a heifer must reach puberty by 11-13 months of age

in order to lead a long, productive life and to be profitable to the cow-calf producer (Larson, 2007).

LITERATURE REVIEW

Estrous Cycle of the Beef Female

Beef females are polyestrous animals whose estrous cycles ranges from 18-24 days (Forde, et al., 2010). The estrous cycle is divided into two phases, based on the prominence of ovarian structures; the luteal phase and follicular phase. The luteal phase lasts from just after ovulation until the regression of the corpus luteum (CL) while the follicular phase lasts from CL regression to the subsequent ovulation (Senger, 2005). The phases of the estrous cycle can be further broken down into four stages.

Stages of the Estrous Cycles

The luteal phase ranges from 14-18 days and includes the metestrus and diestrus stages (Forde, 2010; Senger, 2005). Metestrus begins with ovulation and concludes with the formation of the CL, or 3-4 days. (Senger, 2005; Forde, 2010). The diestrus stage involves the duration of the active CL and is the longest stage of the estrous cycle (Senger, 2005).

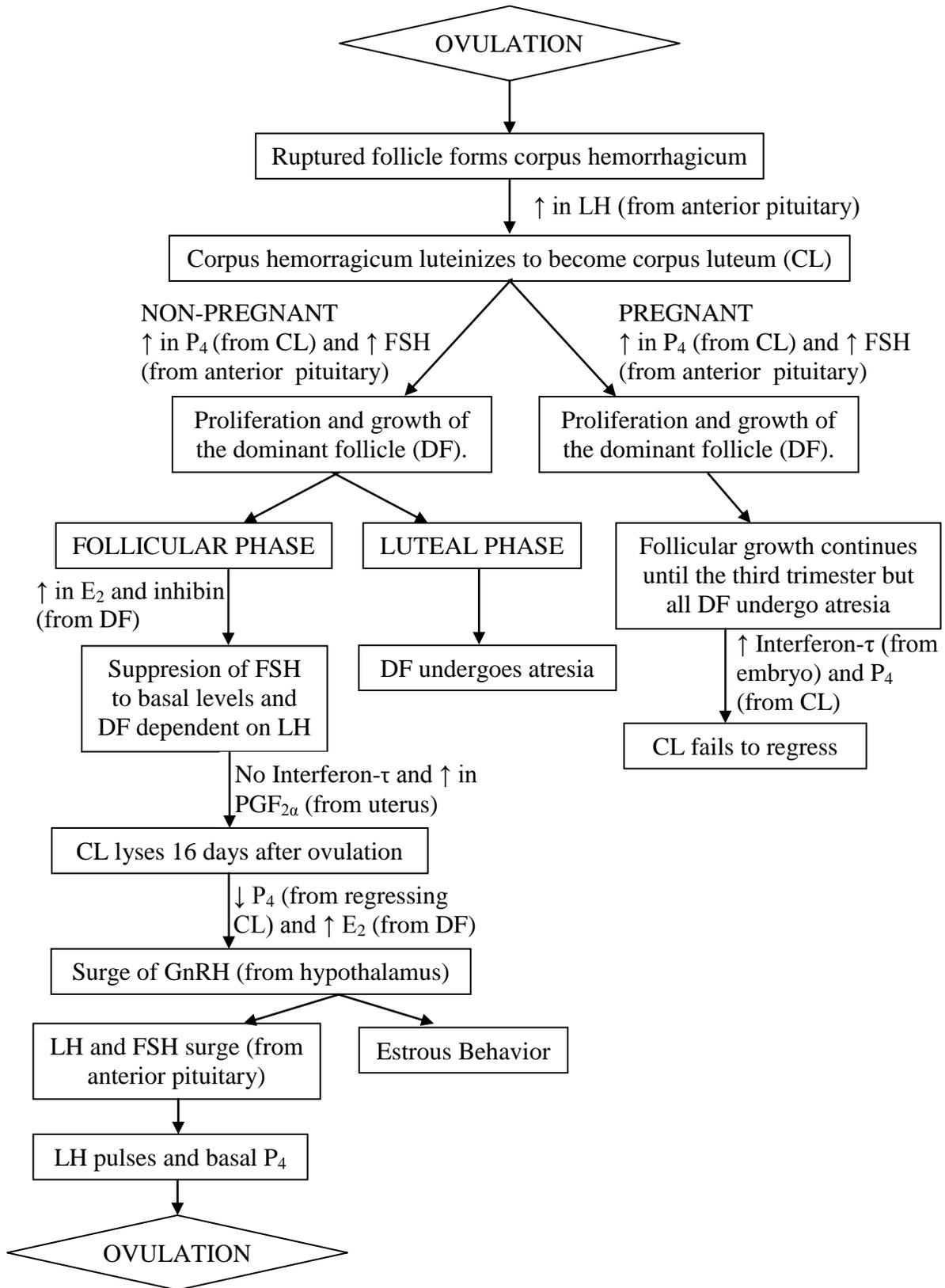
The follicular phase ranges from 4-6 days and includes proestrus and estrus stages (Forde, 2010; Senger, 2005). Proestrus is the time from luteolysis until the time where the female is receptive to mating (Senger, 2005). Estrus is the time which the female is receptive to the male and stands to be mounted by the bull or another female and lasts 6-24 hours (Forde, 2010; Senger, 2005). Ovulation occurs 24-32 hours after the onset of estrus (Senger, 2005).

Hormonal Regulation of the Estrous Cycle

There are many hormones which regulate the estrous cycle. The main hormones involved are gonadotropin-releasing hormone (GnRH), follicle stimulating hormone (FSH), luteinizing hormone (LH), progesterone (P_4), and estradiol (E_2). Ovulation is initiated by a surge of LH in conjunction with low basal progesterone levels from the regressing CL of the previous ovulation. Just after ovulation, the ruptured follicle takes the form of a structure called the corpus hemorrhagicum. This structure, with the aid of LH, transforms into a structure known as the corpus luteum, whose cells produce P_4 . P_4 is important in maintaining pregnancy. P_4 also works with FSH to recruit follicles for future ovulations. The recruitment and growth of these follicles is referred to as the follicular wave (for details see section titled "Antral Follicle Count"). Two of these follicular waves occur during the luteal phase, resulting in atresia of the dominant follicle. However, the third follicular wave, during the follicular phase, results in ovulation of the dominant follicle. The growth and proliferation of cells in the dominant follicle is caused by increased levels of FSH from the anterior pituitary. This dominant follicle produces and secretes E_2 and inhibin which then suppress FSH and the follicle becomes dependent on LH. In non-pregnant females, a lack of interferon-tau (bovine maternal recognition of pregnancy) along with increased concentrations of $PGF_{2\alpha}$ from the uterus causes lysis of the corpus luteum 16 days after ovulation. A reduction in P_4 from the regressing CL in addition to increasing levels of E_2 from the developing dominant follicle cause a surge of GnRH from the hypothalamus. The surge of GnRH initiates estrous behavior as well as

surges of LH and FSH from the anterior pituitary. LH pulses as well as low levels of progesterone lend themselves to ovulation (see Figure1).

Figure 1. Estrous Cycle of the Beef Female



Onset of Puberty in the Beef Heifer

The physiological onset of puberty is defined as the state or stage in development in which the female first expresses behavioral estrus in conjunction with ovulation (Patterson, et al., 1992). Active follicular development of the ovaries is evident even prior to birth. Antral follicles are present at birth and ovulation can be induced as early as one month of age (Schillo, et al., 1992). Ovarian growth is greatest between birth and four months of age, is suspended between five and eight months of age, and then increases until the onset of puberty (Schillo, et al., 1992). Ovarian follicular growth is followed by gametogenesis and then hormone secretion prior to puberty (Patterson, et al., 1992). In an attempt to discover the primary factors for the onset of puberty, it was found that function of the hypothalamic-pituitary-ovarian axis is not the limiting factor since components of the reproductive neuroendocrine axis are active long before the onset of puberty (Schillo, et al., 1992). Pulses of luteinizing hormone (LH) are evident in the peripheral circulation of heifers as early as one month old (Schillo, et al., 1992). The means by which estradiol (E_2) affects LH secretion seems to develop between three and five months of age (Schillo, et al., 1992). It is also thought that pulsatile LH release is necessary for follicles to develop to the preovulatory stage. This pulsatile LH release is necessary for peripubertal heifers, cycling cows, and postpartum cows (Schillo, et al., 1992). Increasing concentrations of E_2 during the follicular phase of the estrous cycle induces the surge of LH (Schillo, et al., 1992). As a heifer gets older, the responsiveness to E_2 negative feedback decreases, causing the LH pulse frequency to increase (Schillo, et al., 1992). The prepubertal increase in pulsatile LH secretion could be the limiting factor in the

physiological onset of puberty (Schillo, et al., 1992). However, the increase in progesterone (P_4) which occurs just before puberty onset is also thought to be a requirement for the development of normal estrous cycles (Patterson, et al., 1992). Coordination of these physiological processes appears to require time to stabilize since the frequency of abnormal cycle length and ovarian/uterine endocrine function is greater prior to the third estrus (Small, et al., 2003).

In mammals, the reproductive system is the last major organ group to develop (Patterson, et al., 1992). The age at which heifers begin regular estrous cycles is correlated with body weight gains from birth to puberty. However, genetic and environmental variables also play a role in the onset of puberty (Patterson, et al., 1992).

Management Factors Which Can Affect the Onset of Puberty

There are many factors that affect puberty onset which the producer may address by proper management. Heifers should reach puberty one to three months prior to the target age at which they are to be bred (Patterson, et al., 1992). Early age at puberty is beneficial to ensure that a higher percentage of heifers are cycling and that fewer heifers are exhibiting pubertal estrus at the initiation of the breeding season (Patterson, et al., 1992). The fertility of heifers bred on their first estrus was 21% lower than heifers bred on their third estrus (Patterson, et al., 1992). There is a correlation between the number of heifers that become pregnant within the defined breeding season and the number that exhibit estrus early in the breeding season (Patterson, et al., 1992).

Phenotype and Genotype

One way producers can manage for early onset at puberty is to select animals that are more likely to reach puberty early due to both their phenotype and genotype. Expected frame size can be used as a tool to develop a proper nutrition program (Patterson, et al., 1992). Body weight is also a valuable tool to consider when managing heifers, especially to allow growth to a female's genetic potential, to ensure high potential fertility (Patterson, et al., 1992). Weight is also important to ensure regular estrous cycles since certain weight gains are necessary for estrous cycles to stay consistent (Patterson, et al., 1992). Many studies show that puberty can be expected at a genetically predetermined size for each individual and, as long as heifers reach that target weight, high pregnancy rates can be obtained (Patterson, et al., 1992). Puberty onset may be the best measure of inherent fertility (Martin, et al., 1992). Age at puberty for heifers and bulls is moderately heritable with heritability ranging from .10 to .67 in various studies (Cushman, et al., 2008). Both natural effects (such as geographic barriers, mutations, and natural selection) and human factors (such as selection for specific traits like milk production, environment resistance, etc.) contribute to the large variation in reproductive traits including onset of puberty between individuals and breeds (Martin, et al., 1992). Heifers sired by bulls from large mature size breeds, such as Charolais and Chianina, tend to be older and heavier at puberty than heifers sired by bulls from smaller mature size breeds, such as Hereford and Angus (Martin, et al., 1992; Bagley, 1993). Breeds that have been selected for high milk production are typically lighter at puberty than those of the same mature size not selected for milk production. For example, high milk-producing breeds

Gelbvieh and Simmental are lighter at puberty than terminally-oriented Charolais or Chianina females (Martin, et al., 1992). There are also differences in onset of puberty between *Bos taurus* and *Bos indicus* females. Brahman-sired heifers are older and heavier at puberty than British breeds or crossbreds (Bagley, 1993). Many studies found that crossbred heifers in general reach puberty at younger ages and heavier weights than their purebred peers (Martin, et al., 1992). The percentage of heifers that reach puberty at a given age is also larger for crossbreds than purebreds (Martin, et al., 1992). However, it is important to consider that although age at puberty was significantly different among breeds, pregnancy rate in yearling heifers was not necessarily correlated to the breed groups that reached puberty at the oldest ages versus the youngest ages (Martin, et al., 1992).

Social and Environmental Factors

Inputs that affect reproduction include variables such as photoperiod, ambient temperature, stress, social interactions, and nutritional status (Schillo, et al., 1992). Proper management of these aspects can benefit a cow-calf operation. Studies have found controversial results in regards to the effects of social and environmental factors on onset of puberty in heifers. There are inconclusive results as to whether exposure to bulls directly affects the onset of puberty. Results of bull exposure vary depending on breed, duration of exposure, nutritional status, body condition, and multiple other variables (Patterson, et al., 1992). Photoperiod studies also have contradicting results due to confounding variables which don't take into account the typical life of the beef heifer such as studies conducted indoors. A study performed outdoors in winter

conditions showed that heifers under extended photoperiod conditions had a 22% improvement in the number of heifers who reached puberty as yearlings in comparison to those raised in normal photoperiod (Small, et al., 2003). Still, photoperiod management is not considered a valuable management tool like it is in seasonal breeders such as sheep (Small, et al., 2003).

Nutrition

Developing a nutrition program which is centered on the needs of the individual herd is imperative to a successful cow-calf operation. Cattle requirements are determined by many things including, but not limited to, class, physiologic status, level of production, level of activity, biologic type, and environmental conditions (Loy, 2007). Nutritional management influences the differences in age and/or weight at puberty onset in heifers (Patterson, et al., 1992).

In response to the discovery of an inverse relationship between body weight and age at puberty, the management strategy to feed heifers to 61-65% of their expected mature body weight at first breeding was developed (Small, et al., 2003). There are conflicting results as to whether the rate of gain has an effect on the onset of puberty. Schillo, et al. (1992) determined that the total amount of growth achieved during the time from weaning to breeding is important rather than the rate or timing of the growth which affects puberty onset. Clanton, et al. (1983) also found no differences on age at puberty or weight gain based on timing of gain during the weaning to breeding period. However, in a study where a high protein diet supported higher rates of gain, the heifers fed high protein reached puberty earlier and had higher

pregnancy rates compared with heifers whose protein was restricted (Patterson, et al., 1992). Heifers fed to gain 1.0 kg per day reached puberty 42.7 days younger than those fed to gain 0.6 kg per day (Hall, et al., 1995). These heifers also had a higher body weight and body condition than those fed for moderate growth (Hall, et al., 1995). It has been thought that lower planes of nutrition actually delay puberty due to effects on the maturation of the reproductive endocrine system (Patterson, et al., 1992). Heifers fed low energy diets took longer to reach puberty and had lower P₄ levels than heifers fed high energy diets (Bagley, et al., 1993). Heifers restricted in energy also showed inhibition of increased LH pulse frequencies in comparison to heifers fed adequate energy (Schillo, et al., 1992).

The nutrition program can have effects on the body condition of the heifer over time. Both over- or under-feeding can cause negative effects on reproduction and/or the onset of puberty. Heifers on different levels of nutrition reach puberty at different ages but at the same relative stage of physical development (Patterson, et al., 1992). Heifers reach puberty sooner and pregnancy rates improve when heifers are sorted according to weight and fed accordingly (Patterson, et al., 1992). Overfeeding heifers can have negative effects on reproduction such as weak estrus behavior, lower conception rates, high embryonic death, decreased mammary development, and lower milk production (Patterson, et al., 1992). However, variability for age and weight at puberty are greatest in undernourished animals (Patterson, et al., 1992). A shortage in protein or energy can cause a growing heifer to be older at puberty, achieve lower conception rates, and lack udder development (Patterson, et al., 1992). Cows with a

body condition score of four or lower have a greater postpartum interval and lower conception rates than those with a body condition score of five or higher (Bagley, 1993).

Other considerations when developing a heifer feeding program are additives such as monensin which alter the rumen environment. Monensin is an ionophore which increases rates of gain (Bagley, 1993). It does this by altering the rumen environment to produce more propionic acid (Bagley, 1993). Altering rumen function works to accelerate the onset of puberty in beef heifers (Patterson, et al., 1992). Diets high in propionic acid result in heifers reaching puberty at lower weights and younger ages (Bagley, 1993).

By-Products

The feed bill is the largest cost on any livestock operation and feed costs represent over 50% of the variation in difference in profit or loss between cattle operations (Rankins, 2002). So, for an operation to be successful, efficient use of inexpensive feedstuffs is ideal. Improving the profit margin is the primary reason for using by-products in the beef cattle industry (Rankins, 2002). A by-product is a secondary feed product obtained during the harvest or processing of a principal commodity. A by-product has value as animal feed whereas it has little value as direct human food (Grasser, et al., 1995). Just about any product with nutritional value can be utilized as a livestock feed by-product. By-products are especially practical for ruminant livestock production due to their ability to process large amounts of fiber

which are commonly found in by-products (Grasser, et al., 1995). By-products of the crop and food processing industries have two important benefits: a) diminishing the dependence on grains which could be used for human consumption and b) eliminating the need for expensive waste management programs for the by-products if they were not used as livestock feed (Grasser, et al., 1995). Due to current environmental and economic concerns, feeding by-products is expected to become a more widely used and efficient practice (Wang and Nishimo, 2008). By-products are low cost feed ingredients which could help reduce the variable cost of livestock production (Grasser, et al., 1995). Locally available by-products from grain and food processing facilities provide a cost-effective source of nutrients to balance the needs of grazing cattle (Loy, 2007). Livestock production facilities located close to metropolitan areas have the advantage of using manufacturing by-products as well (Grasser, et al., 1995). Important factors to consider when contemplating the use of by-products as a cattle feed are moisture content, nutrient profile, contamination possibility, transportation, storage, availability, and regulations (Rankins, 2002). Most of the cost associated with by-products is transportation from the processing facility to the beef operation. In 2002, it was estimated that \$2 per loaded mile was the average transportation cost of by-products (Rankins, 2002). The moisture content can significantly weigh on the decision to use by-products. Wet products have much higher transportation costs per unit of dry matter due to water weight. Most wet by-products are fed within a 100 mile radius of the processing facility (Grasser, et al., 1995).

Grass Seed Straw

In the Pacific Northwest, grass seed is a significant agricultural product (Fisher, et al., 2004). In 2001-2002, Oregon produced approximately 99% of all ryegrass and orchardgrass seed and 64% of all fescue seed harvested in the United States (Bohnert, et al., 2003). Eighty three percent of grass seed production acreage in the Pacific Northwest occurs in the Willamette Valley of western Oregon (Banowetz, et al., 2008). This includes production of annual and perennial ryegrass and tall fescue (Banowetz, et al., 2008). During the grass seed harvest, the head of the plant containing the seed is harvested, leaving behind the stem (grass seed straw, GSS). The traditional manner for straw disposal following seed harvest was historically field burning (Fisher, et al., 2004). Over the past twenty years, air quality regulations and the hazards created from large amounts of smoke have reduced the use of field burning and created a need for more productive uses of the straw (Fisher, et al., 2004; Banowetz, et al., 2008). There is potential to convert the lignocellulosic residues of straw into energy (Banowetz, et al., 2008) One method is by disposing of GSS as a ruminant livestock feed source (Fisher, et al., 2004). Approximately 24,000 square kilometers of straw-yielding cereal grains and grass seed are produced in the Pacific Northwest (Banowetz, et al., 2008). GSS accounts for 14% of the straw in this region (Banowetz, et al., 2008). In 1999, approximately 900,000 tons of GSS were available in Oregon, Idaho, and Washington at 86%, 6%, and 8%, respectively (Bohnert, et al., 2003). Not all straw is available for alternative uses because about 55% of the straw is returned to the soil to reduce soil erosion and improve soil quality (Banowetz, et al., 2008). In the US, less than one percent of the total straw is used as a forage source

(Bohnert, et al., 2003). The majority of the Pacific Northwest's GSS is exported to the Pacific Rim countries of Japan, Korea, and Taiwan (Bohnert, et al., 2003; Fisher, et al., 2004; Banowetz, et al., 2008). These countries imported 613,175 tons of Oregon's grass seed straw in the 2002-2003 market year (Bohnert, et al., 2003). The GSS was sold for \$45-\$50 per ton in 2008 and this profit is spread among straw brokers, storage, compression, and transportation. Very little of the profit actually reaches the seed or grain producers (Banowetz, et al., 2008). However, straw has the potential to provide a low-cost winter supplement similar to other low-quality forages like corn stalks, meadow hay, and sorghum hay (Bohnert, et al., 2003; Fisher et al., 2004). Straw is also a valuable by-product because it can be stockpiled for long periods of time (Bohnert, et al., 2003). Compared with other alternatives, the use of livestock to convert straw to energy is an attractive option due to a growing demand and available transportation systems (Banowetz, et al., 2008). Since the production costs of GSS are already covered by the production of the grass seed itself, straw residues can incur a value-added income to an already successful industry (Banowetz, et al., 2008).

One necessity to make straw a more practical option as a livestock feed is to create small scale collecting, handling, and transportation facilities which are located close to the farm or on-site (Banowetz, et al., 2008). Another concern is improving the digestibility of straw due to its high fiber content. Supplementation of crude protein is an effective way to improve both intake and digestibility of the straw as well as meet the basal protein needs of the animal (Bohnert, et al., 2003). Physical modification by pelleting or grinding the straw does increase intake but decreases digestibility due to a

higher passage rate (Bohnert, et al., 2003). A third option is chemical modification. The most common chemical used is anhydrous ammonia which is readily available in the agriculture industry (Bohnert, et al., 2003). Chemical treatment does improve the rumen degradability of the straw but chemical modification is somewhat inconsistent due to differences in samples such as moisture content and compression of the straw bales (Bohnert, et al., 2003). However, without some type of supplementation or modification, animals, like growing heifers, cannot consume enough GSS to meet their nutritional demands (Bohnert, et al., 2003). Crude protein and total digestible nutrient needs are highest in growing animals and lactating cows (Bohnert, et al., 2003). Therefore, feeding GSS as a large part of the ration without other supplementation should only be practiced in non-lactating, mature cows (Bohnert, et al., 2003).

Another significant concern when using grass seed straw is alkaloids produced by endophytic fungi which form a symbiotic relationship with the grass host (Bohnert, et al., 2003). Two grasses which are commonly produced in the Willamette Valley are perennial ryegrass and tall fescue. Perennial ryegrass contains the endophyte *Neotyphodium lolii* which produces the alkaloid lolitrem B, and tall fescue contains the endophyte *Neotyphodium coenophialum* which produces the alkaloid ergovaline (Fisher, et al., 2004). Both can cause negative effects on livestock if consumed above threshold levels. In the Willamette Valley, 42% of perennial ryegrass samples had greater than 200 ppb ergovaline whereas only 14% of the tall fescue fields had greater than 200 ppb ergovaline (Fisher, et al., 2004). Animals consuming endophyte-free tall

fescue achieve up to twice the gains in comparison to animals fed tall fescue which contained endophytes (Bagley, 1993). A reduction of .07 kilograms per day of gain was found with each 10% increase in endophyte infection of tall fescue (Bagley, 2003). It was also shown that heifers grazing endophyte-containing tall fescue reached puberty at older ages and heavier weights (Bagley, 1993). Reproductive disorders involved with fescue toxicity include increased time to conception, reduced conception and calving rates, and increased embryonic death (Bohnert, et al., 2003).

Feeding perennial ryegrass straw with greater than 2000 ppb lolitrem B can cause neurologic disorders that require additional management (Fisher, et al., 2004). Thirteen out of 24 cows fed a diet containing high levels of lolitrem B experienced clinical signs of uncoordination and tremors without being stressed/handled, indicating they suffered from ryegrass staggers (Fisher, et al., 2004). However, the pre- and post-calving body weights, body condition score, dry matter intake, days to calving of the cows, or calf birth weight was not affected by increasing lolitrem B concentrations (Fisher, et al., 2004).

An important first step in possibly using GSS is to have it tested for alkaloid levels (Bohnert, et al., 2003). Proper management makes it possible to use straws with lolitrem B levels less than 1500 ppb and ergovaline levels less than 400 ppb as a safe, inexpensive, and resourceful cattle feedstuff. (Bohnert, et al., 2003; Fisher, et al., 2004)

Wet Brewers' Grain

More than 195 million barrels of beer were produced in the US in 2005 (Loy, 2005). There are currently 81 brewing companies which operate 113 brewing facilities located in 43 cities in Oregon (Oregon Brewers Guild, 2009). Oregon produced more than one million barrels of beer in 2009 (Oregon Brewers Guild, 2009). As a by-product of the brewing industry, brewers' grains (BG), also known as spent grains, are 100% utilized for cattle feed (Grasser, et al., 1995). Wet brewer's grain (WBG) is the residue obtained after extracting wort from barley malt or a mixture of other cereal grains (Grasser, et al., 1995; Westendorf and Wohlt, 2002; Wang and Nishino, 2008). BG is available in both wet and dried forms. Fifty to 100,000 tons of dried brewers' grain (DBG) is marketed each year (Westendorf and Wohlt, 2002). DBG does have advantages in terms of storage and shelf life, but the costly process of drying makes it less economical for cattle producers.

BG are mostly structural carbohydrates and protein remaining when barley is malted and then mashed to release sugars for brewing (Westendorf and Wohlt, 2002). The two main nutrients in BG are crude protein (about 25% DM) and neutral detergent fiber (about 50% DM) (Westendorf and Wohlt, 2002). The protein levels in BG are considered intermediate but may be greater in ruminant diets because of its bypass potential (Westendorf and Wohlt, 2002; Loy, 2007) Energy levels are considered low at about 66% total digestible nutrients (Loy, 2007). However, the nutritional value in spent grains is often greater than that of the foundation grains. The crude protein content of BG is about double that of the foundation grains due to the removal of soluble carbohydrates (Westendorf and Wohlt, 2002). BG are also higher in fiber and

some minerals due to the removal of starches and sugars in the malting and mashing process (Westendorf, and Wohlt, 2002).

WBG is gaining popularity over DBG for four main reasons. First, the high cost of the drying process makes DBG difficult to justify from an economic standpoint. Second, dairies have a greater demand for WBG because they have a high turnover of feed and can utilize it quickly. Third, due to the seasonality of beer production, spent grains are marketed all at once as WBG to meet demand rather than dried and offered year-round. Finally, huge improvements have been made in transportation, making wet brewers' grain more easily accessible (Westendorf and Wohlt, 2002). Also, no major differences have been found in terms of production between feeding wet or dried brewer's grain. The value of DBG and WBG is similar in lactating cows fed 15% of dietary dry matter in a total mixed ration containing similar dry matter (Dhiman, et al., 2003). Dry or wet brewers' grain had no effect on feed intake, milk yield, milk composition, or feed consumption (Dhiman, et al., 2003). WBG can be validated from both nutritional and economic standpoints but it can only be fed in limited amounts without affecting dry matter intake and performance (Westendorf and Wohlt, 2002).

The biggest issue relating to WBG is spoilage, which results in a less palatable product and animal health concerns (Westendorf and Wohlt, 2002). The cost effectiveness of WBG also comes into question if spoilage occurs. The product must be utilized quickly or stored correctly (Westendorf and Wohlt, 2002). The average moisture in WBG is 70-80% which is typical for a high-moisture by-product (Rankins,

2002). An uncovered pile of WBG has an average storage life of less than 5-7 days (Westendorf and Wohlt, 2002). Because of this, it is imperative that ranchers coordinate with microbreweries to get an understanding of the brewing schedule. WBG may also be sealed in plastic to help avoid aerobic spoilage (Westendorf and Wohlt, 2002). Ensiling may also be a possible storage solution for WBG, utilizing anaerobic fermentation as a form of preservation (Westendorf and Wohlt, 2002). When ensiled alone, WBG spoiled quickly. However, when mixed into silage as part of a total mixed ration, no heating was shown for seven days (Wang and Nishino, 2008). However, WBG fed as a part of a total mixed ration greatly reduces its bunk life, especially during the summer (Westendorf and Wohlt, 2002).

Like grass seed straw, BG can contain toxic compounds. Mycotoxin contamination is a concern to producers because it can have adverse effects on animal health (Westendorf and Wohlt, 2002). The amount of toxin found in the foundation barley or corn in addition to the water solubility and heat stability of the toxin are key factors to determine if spent grains will contain mycotoxins (Westendorf and Wohlt, 2002). Barley's biggest mycotoxin threats are vomitoxin and zearalenone while corn's biggest concern is fumonosins (Westendorf and Wohlt, 2002). Aflatoxin results in reduced growth rate, decreased productivity, suppressed immune system, liver damage, underweight calves, and decreased reproductive performance (Cheeke, 1998). Toxicity by tricothecene family members vomitoxin and T-2 toxin are recognized by feed refusal, ruminal ulcers, vomiting, skin inflammation and necrosis, and hemorrhaging of the gastrointestinal tract (Cheeke, 1998). Like alkaloids, BG likely to

contain mycotoxins should be tested. However, with proper management, BG is a valuable feedstuff.

Quantitative Markers for Onset of Puberty

Although management can play a role in heifers reaching puberty onset, there are several biological markers we can monitor to try to determine when a heifer will reach puberty. This allows the producer to try to predict which females will reach puberty more quickly, which is a benefit for any cow-calf producer.

Scrotal Circumference

Scrotal circumference (SC) has been correlated with age at puberty in both a bull's male and female offspring (Martin, et al., 1992). Yearling SC had positive genetic correlations with puberty onset and pregnancy rate in heifers (Cushman, et al., 2008). Heritability for SC ranges from .26 to .67 in various studies (Martin, et al., 1992) SC may be an economical way to measure daughter reproductive capability. It is an inexpensive, time-effective way to evaluate puberty onset because it doesn't require any lab techniques or daily estrus detection (Cushman, et al., 2008). Regressions of -0.8 days in age at puberty, -0.67 days in first calving date, and -0.83 days in age at first calving of female offspring per centimeter of SC of her sire have been discovered (Martin, et al., 1992).

Antral Follicle Count

The two main purposes of the bovine ovary are to produce fertilizable, viable oocytes and to secrete hormones which are vital for the proper function of the reproductive tract and establishment and maintenance of pregnancy (Knight and

Glister, 2006). The number of healthy oocytes in the ovary of mammalian females (ovarian reserve) is extremely variable at birth, ranging from 14,000 to 250,000 in cattle (Ireland, et al., 2008). Cows selected for increased ovulation rate resulted in an increase in the ovarian reserve (Cushman, et al., 2009). The ovary is responsible for housing oocytes within a structure called the follicle which changes as the oocyte matures. The number of follicles, oocytes, and oocyte quality decreases quickly as aging occurs (Ireland, et al., 2009). This aging, known as reproductive senescence in the cow or menopause in women, depletes the ovarian reserve and decreases follicle numbers, which could be an indicator of lifelong productivity (Cushman, et al., 2008). Ovarian follicle growth includes the growth of multiple follicles but results in the selection of a single dominant follicle which may mature completely and ovulate. Cattle experience 2-3 follicular waves during each estrous cycle (Mihm, et al., 2002; Senger, 2005). The dominant selected follicle from the first 1-2 waves undergoes atresia while the dominant selected follicle from the final wave ovulates (Senger, 2005). In fact, follicular waves continue even in the pregnant cow for the first two trimesters of gestation (Forde, 2010). In cattle, it takes more than 30 days for an antral follicle to grow from 300 μm to 3-5 mm which can be distinguished by transrectal ultrasound (Mihm, et al., 2002). Pre-follicular wave FSH leads to the selection of the dominant follicle and is seen in all reproductive states in the beef female including before puberty, during the estrous cycle, during pregnancy, and during postpartum or nutritional anestrus (Mihm, et al., 2002). Active follicular development of the ovaries is evident even prior to birth. Antral follicles are present at birth and ovulation can be

induced as early as one month of age (Schillo, et al., 1992). A follicle is considered healthy if it demonstrates an intact basal membrane, organized granulosa cells with few pyknotic nuclei or atretic bodies, and an intact oocyte with intact nucleus (Ireland, et al., 2008).

The amount of follicles a female's ovaries produce could be a marker to help determine her value as a replacement female. Antral follicle count (AFC) is the number of follicles in the tertiary or Graafian (quaternary) stage on the ovary at any given time. AFC can be evaluated via transrectal ultrasound by estimating the number of follicles with a diameter greater than 3 mm (Ireland, et al., 2008). AFC increases in cows until age 5 and then declines (Cushman, et al., 2009).

Such non-invasive methods to classify AFC could be instrumental in predicting reproductive lifespan and improving livestock breeding programs via increased herd fertility (Ireland, et al., 2008). Determining AFC in heifers prior to breeding could possibly identify highly fertile heifers that will produce large numbers of calves (Cushman, et al., 2008). Heifers born with less than 100,000 primordial follicles in their ovarian reserve had fewer growing secondary and antral follicles (Cushman, et al., 2008).

There are multiple studies which have looked at the consequences of heifers with low AFC versus high AFC. Low AFC was associated with decreased pregnancy rate in heifers (Cushman, et al., 2009). Total number of healthy follicles and number of follicles per gram of ovary was lower in low versus high AFC females (Ireland, et al., 2008). Number of morphologically healthy follicles in primordial, transitory,

primary, secondary, and antral follicles was lower in low AFC versus high AFC heifers (Ireland, et al., 2008). Weight, height, and length of ovaries was smaller in low AFC versus high AFC heifers (Ireland, et al., 2008).

Although transrectal ultrasound is a non-invasive method to determine AFC, it requires an experienced technician to observe each heifer daily for at least one follicular wave (5-8 days). This method is time-consuming and labor-intensive. Recent research has recognized Anti-Mullerian Hormone (AMH) as an indicator of AFC which would allow a single blood collection to evaluate ovarian reserve in beef females.

Anti-Mullerian Hormone

Anti-Mullerian Hormone, also known as Mullerian Inhibiting Substance, is a dimeric glycoprotein member of the TGF- β superfamily (La Marca, et al., 2009). The TGF- β family members are similar in terms of their structure but they serves many different physiological purposes throughout the body of more than 35 identified species in both pre- and post-natal life (Knight and Glister, 2006). Experimental evidence shows that TGF- β superfamily members have various roles in reproductive physiology including primordial follicle recruitment, granulosa and thecal cell growth and atresia, steroidogenesis, gonadotropin receptor expression, oocyte maturation, ovulation, luteinization, and corpus luteum formation (Knight and Glister, 2006). However, AMH's best understood function is in male sex differentiation (La Marca, et al., 2009). AMH is produced by Sertoli cells of the developing male gonad and causes the regression of the Mullerian ducts (La Marca, et al., 2009). Without AMH, the

Mullerian ducts become the uterus, oviducts, and cranial portion of the vagina (La Marca, et al., 2009).

AMH is produced in bovine cumulus and granulosa cells (Ireland et al., 2009). AMH receptors are located in granulosa cells (Ireland, et al., 2009). AMH gene expression is shown to be altered in bovine and rodent granulosa cells during follicular development (Ireland, et al., 2009). AMH expression is absent in primordial follicles (La Marca, et al., 2009). Strongest staining of AMH appears in the pre-antral and small antral follicles (La Marca, et al., 2009). AMH continues to be expressed until growing follicles have reached the size and differentiation state at which they can be chosen for dominance (La Marca, et al., 2009). Granulosa cells express AMH until the early (mouse), mid-antral (human), or pre-ovulatory (sheep) stage (Knight and Glister, 2006). AMH is not expressed in thecal cells or atretic follicles (La Marca, et al., 2009).

AMH appears to have multiple roles in the regulation of folliculogenesis. It has an inhibitory effect on primordial follicle growth (Knight and Glister, 2006). Exposure of neonatal ovaries to AMH in vitro was found to halve the number of growing follicles (Knight and Glister, 2006). Without AMH, primordial follicles are recruited at a much higher rate, causing the ovarian reserve to deplete prematurely (La Marca, et al., 2009). Endogenous AMH negatively affects pre-antral development past the primordial to primary stages (Knight and Glister, 2006). AMH reduces sensitivity to FSH and may negatively affect the recruitment of follicles and the dominant follicle selection progression (Knight and Glister, 2006).

AMH may be used as a fertility marker in cattle. Circulating AMH concentrations are positively associated with AFC in cattle, and, therefore, heightened fertility (Ireland, et al., 2009). Circulating AMH concentrations were approximately 6- and 2-fold greater in cattle with high and intermediate AFC, respectively, in comparison to heifers with low AFC (Ireland, et al., 2008). AMH mRNA was about 20-fold higher for high AFC females versus low AFC (Ireland, et al., 2009). Marked variation in AFC during follicular waves was highly positively correlated (0.8-0.9) with circulating AMH concentrations, ovary size, and total number of morphologically healthy oocytes in heifers of a similar age and body weight (Ireland, et al., 2008). Young cattle with low AFC have high circulating FSH and LH concentrations and low circulating concentrations of AMH and P₄ during their estrous cycles (Jimenez-Krassel. et al., 2009). Cattle with low AFC also had reduced response to superovulation, lower number of high quality transferrable embryos, a reduced number of high quality oocytes, and reduced in vitro blastocyst development in comparison with similar animals with high AFC (Jimenez-Krassel, et al., 2009).

The characteristics found in relation to AMH are also relevant to humans. Cattle are an excellent model for AMH and AFC research for two main reasons. Female cattle are a single ovulating species who have 2-3 follicular waves in a fairly long reproductive cycle like women (Ireland, et al., 2008). Also, follicular waves are highly reproducible within healthy individuals (Ireland, et al., 2008). Non-invasive methods for determining ovarian reserve could have profound effects on human reproductive medicine (Ireland, et al., 2008). Potential uses are family planning by

gauging the impact of disease, nutrition, and therapy on the reproductive system and reproductive lifespan (Ireland, et al., 2008). Measuring serum AMH may be an effective way to measure ovarian reserve in women (Knight and Glister, 2006). Circulating AMH concentrations in women are highly correlated with the number of antral follicles found by transvaginal ultrasound and, it is inferred, with size of the ovarian reserve (Knight and Glister, 2006). Serum AMH concentrations in normal cycling women decrease with age and are undetectable in post-menopausal women (Knight and Glister, 2006). AMH concentrations steadily decline in women in relation to follicular reserves while FSH and Inhibin B were not as consistent, indicating that AMH may be the best marker for ovarian aging and onset of menopause (La Marca, et al., 2009). Serum AMH may help identify precursors of menopause or ovarian follicular pool assessment, especially in those women with hypergonadotropic disorders (La Marca, et al., 2009). AMH could also be used as an ovarian function marker in women who have undergone chemotherapy or radiation treatments (La Marca, et al., 2009). Serum AMH concentrations could possibly be used to diagnose Premature Ovarian Failure in women (La Marca, et al., 2009). AMH could be instrumental in diagnosis of polycystic ovary syndrome. AMH levels average 75 times higher in granulosa cells from polycystic ovaries versus normal ovaries (La Marca, et al., 2009). Finally, AMH has been shown to be a circulating marker for Granulosa Cell Tumor, and, therefore, could be used in the diagnosis or treatment of ovarian cancer (La Marca and Volpe, 2007).

MATERIALS AND METHODS

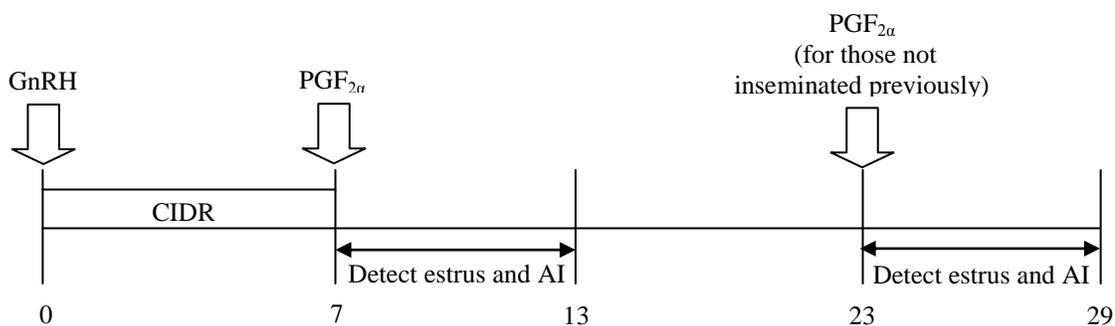
Animals

Eighteen Angus-influenced crossbred heifers (initial body weight = 561 ± 11.4 lbs and age = 278 ± 2.4 days) were utilized in this experiment. Heifers were confirmed prepubertal at the onset of the study via rectal palpation for ovarian structures. Heifers were housed at the OSU Steer-A-Year barn and randomly assigned to one of four pens and one of three treatment groups within a pen. Pens were of equal size and each pen contained five feed bunks equipped with Calan Gates (American Calan, Northwood, NH) to allow individual feeding. Heifers were given a forty-day adaptation period to become accustomed to utilizing Calan gates in the experimental pens. During this pre-conditioning time, heifers were allowed ad libitum access to grass hay fed twice daily. The feeding trial began on December 7, 2009 and continued for 154 days.

At the conclusion of the feeding trial (Day 154), all heifers were fed the control diet and estrous synchronized using the Select Synch + CIDR (Pfizer Animal Health, New York, NY) protocol. Heifers displaying estrus were inseminated twelve hours after onset with one straw of frozen semen. Heifers not displaying estrus were injected with 25 mg of PGF_{2 α} (Lutalyse, Pfizer Animal Health, New York, NY) ten days after the initial PGF_{2 α} injection in the Select Synch + CIDR protocol, subsequently observed for estrus, and inseminated as described (Figure 2). Heifers were observed for at least 30 days after insemination. Any heifer displaying estrus was re-inseminated. All heifers were inseminated with semen from a single collection from one sire. After a second opportunity for artificial insemination, heifers were transported to the OSU Soap Creek Ranch where they were pastured with an Angus

bull for 38 days. Heifers remained at the OSU Soap Creek Ranch for the majority of their gestation until they returned to the OSU Campus Beef Unit approximately 30 days prior to the expected start of the calving season.

Figure 2. Modified Select Sync + CIDR estrous synchronization and artificial insemination (AI) protocol



The animals utilized in this experiment were cared for in accordance to the Institutional Animal Care and Use Committee of Oregon State University.

Diets

The experimental treatments were roughage source: grass hay serving as the control, tall fescue straw, or tall fescue straw ensiled with brewer's grain. A unique concentrate was developed for each roughage in order to develop an iso-nitrogenous and iso-caloric diet (Table 1). Heifers were offered a ration balanced to meet a goal of 1.3 pounds of gain per day. Monensin sodium (Rumensin, Elanco, Greenfield, IN) was added to the concentrate so that each heifer received 400 mg per day.

Feed delivered to the bunk was weighed and recorded. Orts were removed from each feed bunk and weights were recorded as necessary to ensure fresh feed was provided for each heifer on a daily basis and to track intake.

Table 1. Composition of concentrates fed in experimental diets

	Concentrate (% of ingredient)		
	Concentrate A (Hay ration)	Concentrate B (Straw ration)	Concentrate C (Silage ration)
Barley	72.51	56.77	70.74
Soybean	21.30	37.65	
Molasses	4.00	4.00	4.00
Calcium Carbonate	1.40	1.00	1.75
Salt	0.49	0.35	0.61
Mineral Mix	0.22	0.18	0.25
Monensin	0.09	0.06	0.11
Canola			22.55

Grass Hay Ration (HAY)

Ryegrass hay was cultivated and baled at the OSU Soap Creek Ranch. Hay was chopped to approximately 3 inch lengths using a vertical mixer (502 NE Vertical Mixer, Sioux Falls, SD).

Tall Fescue Straw (STRAW)

Fescue straw was chopped to approximately 3 inch lengths using a vertical mixer. Straw was evaluated for endophytes prior to the study (Oregon State University Endophyte Testing Lab, Corvallis, OR). Ergovaline concentration was less than 100 ppb and Lolitrem B concentration was at 595 ppb. Both were considered safe to feed to livestock.

Tall Fescue Straw / Wet Brewer's Grain Silage (SILAGE)

On August 26, 2009, wet brewer's grain was delivered to the Steer-A-Year Barn from Volbeda Dairy in Salem, Oregon. The wet brewer's grain was ensiled with tall fescue straw (same source as STRAW diet) with 30% of the silage composed of wet brewer's grain and the remaining 70% composed of tall fescue straw. Water was added to make the silage approximately 70% in moisture. Content feedstuffs were thoroughly mixed in a vertical mixer. Silage was packed and stored in an Ag-Bag (Miller-St Nazianz, St Nazianz, WI) until the start of the feeding trial on December 7, 2009.

Sampling

Heifers were weighed and blood samples were collected weekly (Tuesday) throughout the feeding trial. Plasma concentrations of progesterone were used as an indicator of puberty status. Onset of puberty was considered the first week in which plasma progesterone concentration exceeded 1.0 ng/mL. Circulating concentration of anti-Mullerian hormone was determined to explore its possible role in puberty onset. Blood samples were collected via coccygeal venipuncture in 10-mL Vacutainer tubes containing 100 µl EDTA.

Heifers were weighed 30 days prior to the expected start of the calving season on January 16, 2011.

Blood Analysis

Whole blood was centrifuged at 3000 x g for 15 minutes and plasma was harvested and stored at -20°C until analyzed for progesterone. Progesterone concentrations were determined using an ELISA (#1860, Alpha Diagnostics, San

Antonio, TX). Intra- and inter-assay CV were 6.74% and 14.3% respectively, and assay sensitivity was 0.2 ng/mL.

Anti-Mullerian Hormone concentration was determined using an ELISA (#A79765, Beckman Coulter, Brea, CA). Because AMH concentrations are relatively low in bovine compared with humans, the protocol was adjusted to use 40 μ l rather than 20 μ l of serum during assays.

Calving Data

Heifers were scored for calving ease (Table 2) and a vigor score was assigned to each calf (Table 3). Calf birth weights were recorded within 24 hours of birth using a digital scale.

Table 2. Scoring system for calving ease

Score	Description
1	No assistance, calf born normally
2	Assisted, easily
3	Assisted, very difficult
4	Caesarian birth
5	Abnormal presentation

Table 3. Scoring system for calf vigor

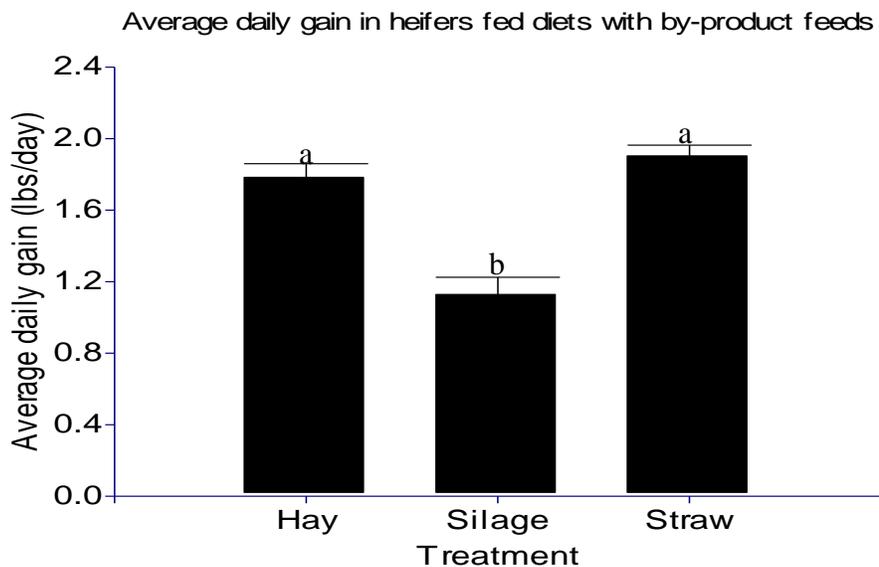
Score	Description
1	Nursed within 45 minutes of birth, calf was healthy and strong at birth
2	Nursed on its own but took greater than 45 minutes
3	Required some assistance to suckle
4	Died shortly after birth
5	Dead on arrival

RESULTS

Body Weight

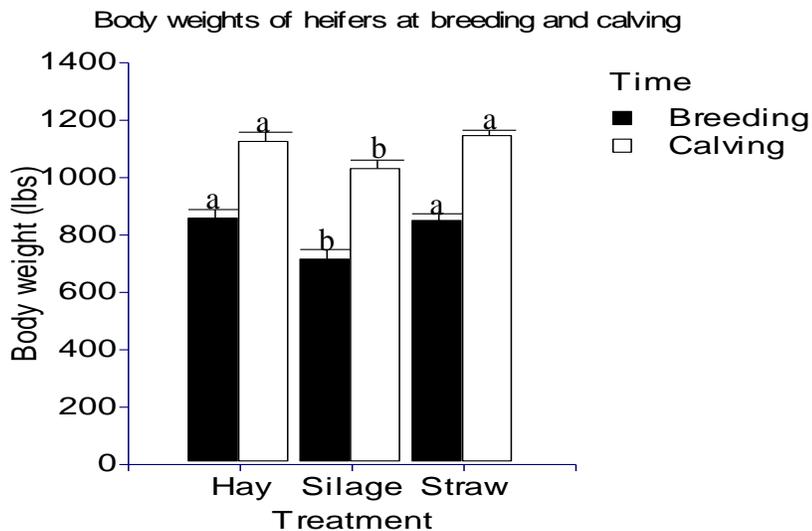
No differences ($P>0.10$) in body weights at the onset of the study were observed. Average daily gain in SILAGE heifers was lower ($P<0.05$) than HAY and STRAW heifers (Figure 3). SILAGE heifers had lower ($P<0.005$) body weights at the start of the breeding season than HAY and STRAW heifers (Figure 4). SILAGE heifers also had reduced ($P<0.03$) body weights 30 days prior to the expected start of the calving season than HAY and STRAW heifers (Figure 4).

Figure 3. Average daily gains in heifers fed HAY, SILAGE, and STRAW diets



^{a, b}: Treatment means that do not have common superscripts differ ($P<0.05$)

Figure 4. Mean body weights of heifers at breeding and 30 days prior to the expected onset of calving



^{a, b}: treatment means that do not have common superscripts differ ($P < 0.05$)

Puberty Onset

No differences were observed in mean body weights (Figure 5), ages at puberty onset (Figure 6), or percentages of heifers attaining puberty due to treatment (Figure 7).

Figure 5. Mean body weights at puberty onset

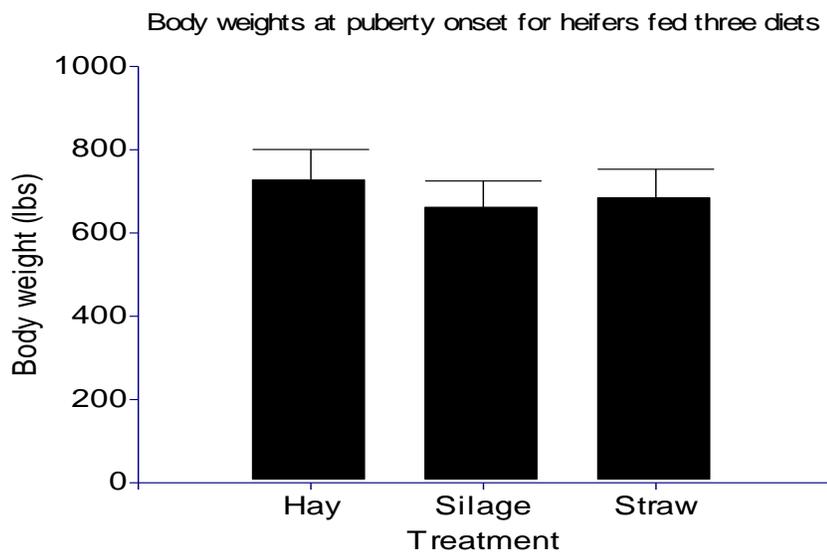


Figure 6. Mean ages at puberty onset

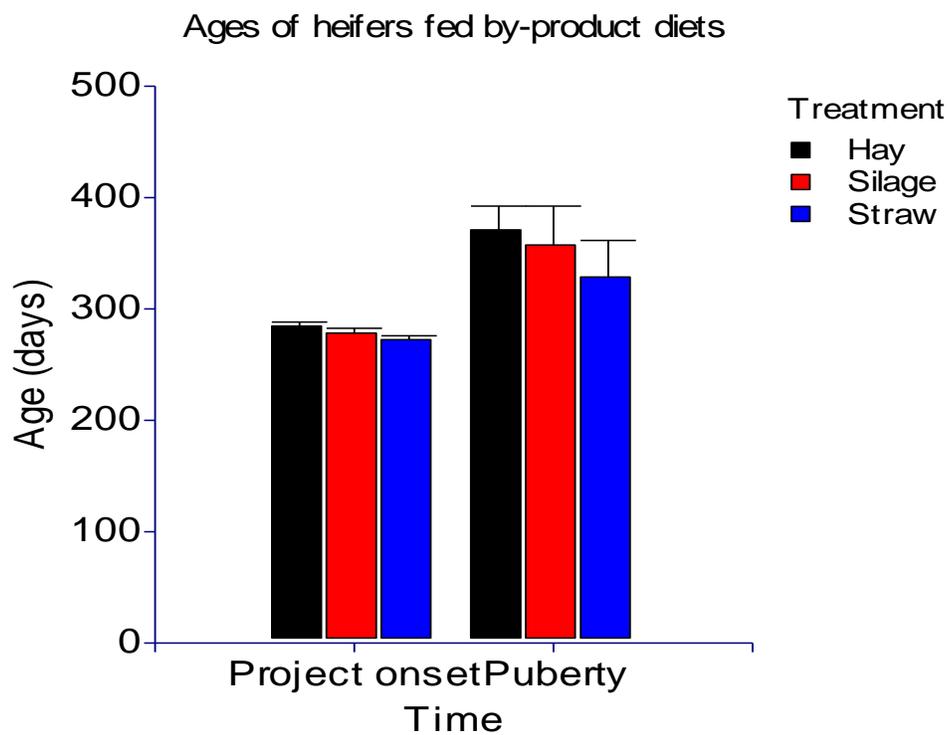
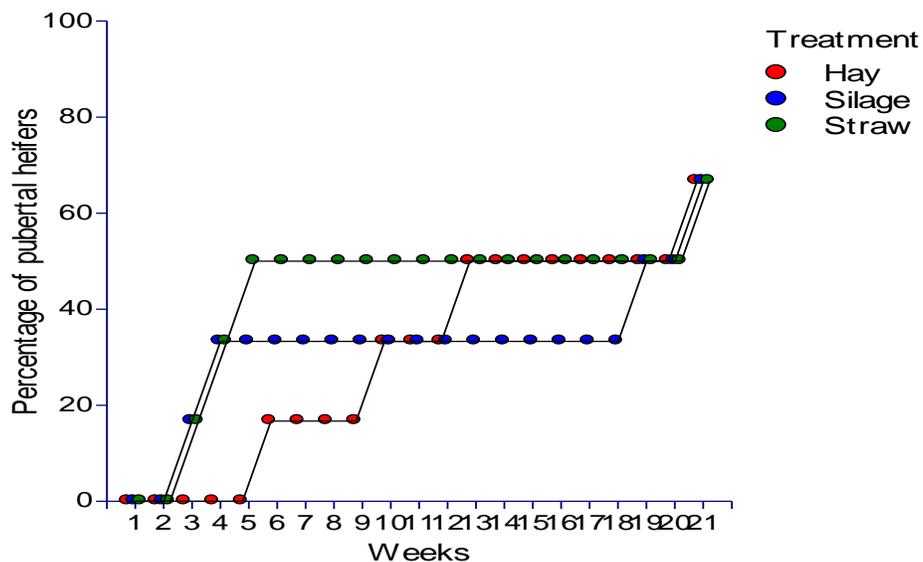


Figure 7. Percentage of heifers attaining puberty

Percentages of heifers fed by-product diets attaining puberty



Breeding and Calving Data

No differences were observed due to diet in services per conception (Figure 7), calving ease scores (Figure 7), calf vigor scores (Figure 7), or calf birth weights (Figure 8).

Figure 8. Mean services per conception, calving ease scores, and calf vigor scores

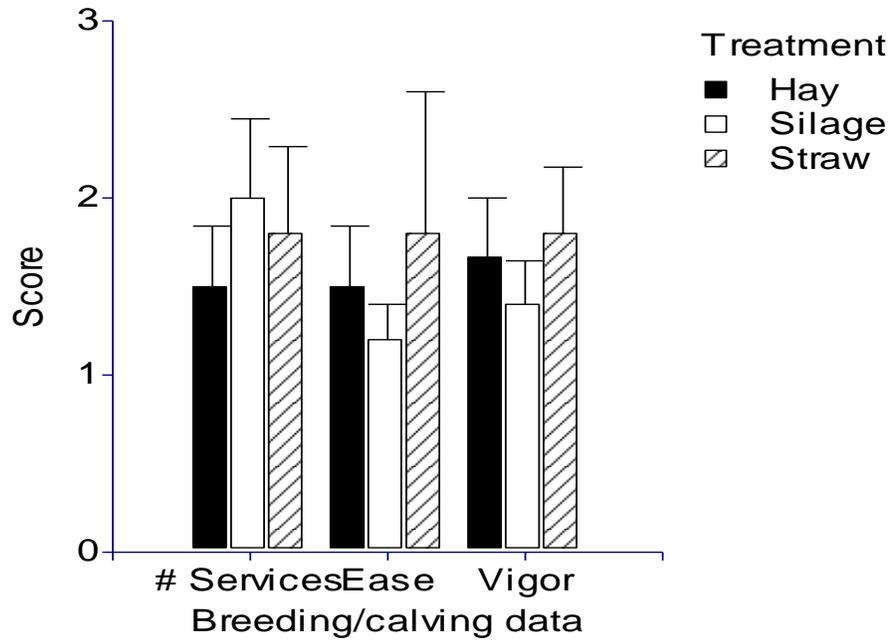


Figure 9. Calf birth weight by treatment

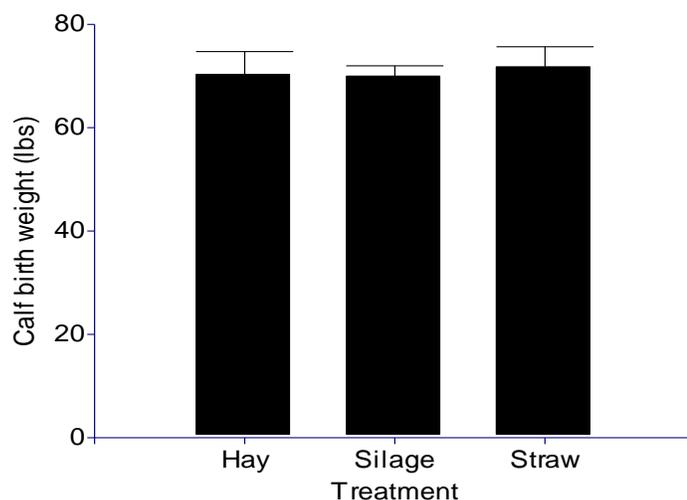


Table 4. Percentages of heifers displaying estrus and conception rates

	HAY	SILAGE	STRAW
Heifers displaying estrus following first PGF _{2α} injection	4/6 (66.7%)	4/6 (66.7%)	4/6 (66.7%)
Heifers displaying estrus following second PGF _{2α} injection	2/6 (33.3%)	2/6 (33.3%)	2/6 (33.3%)
Total heifers displaying estrus	6/6 (100%)	6/6 (100%)	6/6 (100%)
Heifers pregnant by first AI	4/6 (66.7 %)	2/6 (33.3%)	3/6 (50%)
Heifers pregnant by second AI	1/6 (16.7%)	1/6 (16.7%)	0/6 (0%)
Total heifers pregnant by AI	5/6 (83.3%)	3/6 (50%)	3/6 (50%)
Heifers pregnant by natural breeding	1/6 (16.7%)	2/6 (33.3%)	2/6 (33.3%)
Overall conception rate	6/6 (100%)	5/6 (83.3%)	5/6 (83.3%)

Pending Data

Plasma AMH concentrations will be analyzed for possible correlations with onset of puberty. Post-partum resumption of estrous cycles will be determined by

plasma progesterone analysis by ELISA. All first-calf heifers will be estrous synchronized, artificially inseminated, and services per conception determined. Finally, weaning weights of calves will be compared between treatments.

DISCUSSION

Diet

The results provide cattle producers new possible feedstuffs to utilize in the future. Our results are exciting because they demonstrate that inexpensive by-product feedstuffs can be used to replace more expensive roughages like hay. However, there are a few things to consider when utilizing these products. Grass seed straw must be tested for endophytes to avoid negative effects on health. Also, like any silage, grass seed straw/ brewer's grain silage needs to be maintained properly and its effective use may be limited by the number of heifers a producer is developing. In our study, where only 6 heifers were being developed, prevention of mold growth was difficult. Although the Ag-Bag was resealed as much as possible, the silage still degraded fairly quickly. However, in an operation which is developing a large amount of heifers where the silage can be used very quickly, it could prove to be a very valuable feedstuff.

Body Weight and Onset of Puberty

In a management scenario, it's typical for a heifer to reach 61-65% of her mature weight at her first breeding (Smalls et al., 2003). The expected mature weight for our heifers, based on the average cow size in the herd, was 1300 pounds. Heifers fed HAY, the control treatment, and STRAW reached 66 and 65% of mature weight at breeding, respectively, whereas heifers fed the SILAGE reached 55% of the mature weight at breeding. Although the SILAGE group had lower average daily gain throughout the feeding trial and lower weights at breeding and calving, these heifers still reached puberty at the same weight and age as the HAY and STRAW groups.

Martin et al. (2007) observed similar results when supplementing dried distillers grains. In this study, heifers fed dried distillers grains reached puberty at the same body weight and age as control heifers. These results conflict with multiple other studies. Roberts et al. (2009) saw a 9% decline in heifers who reached puberty when fed to 55 to 58% of their mature weight in comparison to peers fed to 60-68% of their mature weight. These results were similar to an 11% decrease in puberty onset in spring born heifers fed to 53% of their mature body weight in comparison to those fed to 58% of mature body weight (Funston and Deutscher, 2004). Martin et al. (2008) observed that 17% fewer heifers reached puberty by their first breeding season when fed to 51% of their expected mature weight in comparison to those fed to 58% of their mature weight. Roberts et al. (2009) also observed that every centimeter increase in hip height reduced the proportion of heifers who reached puberty by $1.89 \pm .82$.

Breeding and Calving Data

Although SILAGE heifers had lower average daily gain throughout the feeding trial and lower weight at breeding and calving, their lighter weight did not negatively affect the reproductive measurements we observed. These results are similar to Martin et al (2008) who observed that heifers in a relaxed development program reached 50.9% of their expected mature body weight, while heifers raised intensively reached 56.5 % of their expected mature body weight at breeding. Although only 34.9% of the relaxed developed heifers were pubertal at the onset of the breeding season in comparison to 52.1 % in the intensively developed heifers, no differences in pregnancy rate were observed between the two treatments. In the same study, pre-

calving weights were also greater in intensively raised heifers compared to relaxed developed heifers. However, there were no significant differences were detected in birth weight or calving difficulty. Some conflicting research to these results exist. Roberts et al. (2009) found that heifers developed on a restricted diet tended to have lower conception rates. But differences in services per conception were not significant.

Several conclusions can be made from the results of our study. SILAGE heifers had lower average daily gain and lighter weights at breeding and calving. But, there were no significant differences in ages or weights at puberty onset or the percentages of heifers who reached puberty onset among treatments. In addition, no significant differences were detected in services per conception, calving ease score, calf vigor score, and calf birth weight. These results suggest that heifers fed the less expensive, by-product STRAW ration have weight gain and reproductive performance similar to heifers fed a traditional HAY ration. Although heifers fed the SILAGE diet had lighter body weights, a negative impact on reproductive measurements was not observed, suggesting the ration was adequate to support reproductive performance similar to a traditional HAY ration.

The conclusions from the study demonstrate that grass seed straw and brewer's grain are great prospects as feedstuffs in future heifer development programs. In addition to being inexpensive, these by-products have positive effects on the environment by preventing field burning and reducing the need for waste management programs.

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