© 2017 IJSRST | Volume 3 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Using of Sugar Beet Pulp By-Product in Farm Animals Feeding

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ABSTRACT

Sugar beet pulp is a by-product from the processing of sugar beets into sugar. Beet pulp is extracted grounded sugar beet. It is used as livestock feed and it can be fed fresh, dried and ensiled (fermented beet pulp). Sugar beet pulp is a by-product from the processing of sugar beet which is used as fodder for cattle and other livestock. It is supplied either as dried flakes or as compressed pellets. Sugar beet pulp is a highly palatable feed with good energy levels. Sugar beet pulp is low in sugar and other non-structural carbohydrates. Contains highly digestible fibre which is suited to ruminants as it maintains rumen condition and encourages acetate production. It has a high liquid absorbency and can, therefore, be used as a silage additive to retain the feed value from effluent. Another by-product from the processing of raw sugar cane is cane molasses. This is usually mixed with the sugar beet pulp to form molasses sugar beet when it is dried and pressed and distributed as shreds or pellets. The fibrous residues of sugar beet comprise mainly cellulose, which is highly digestible. Thus when fed with an appropriate supplement of degradable protein, sugar beet is an exceptionally suitable feed for ruminants, helping to promote optimum rumen conditions and boosting milk production. After the sugar has been extracted from sugar beets, the fibrous portion of the sugar beet is dehydrated. Dried beet pulp shreds have a very low bulk density so are often processed into pellets or cubes for transport. Both shreds and pelleted /cubed beet pulp is used in animals feed. Despite being called sugar beet pulp, beet pulp contributes very little sugar to the diet. Beet pulp, which commonly is used in beef cattle diets as a supplement or roughage replacement in finishing diets, is the beet shreds left over from processing. This feed is high in energy and fiber. Beet pulp is supplied either as dried flakes or as compressed pellets. Despite being a byproduct of sugar beet processing, beet pulp itself is low in sugar and other non structural carbohydrates, but high in energy and fiber and contains 0.8 % calcium and 0.5 % phosphorus.

Keywords: Sugar Beets, Animal Feeding, Growth, Blood Composition, Milk Yield and Composition.

INTRODUCTION

Sugar beet, cultivated *Beta vulgaris,* is a plant whose root contains a high concentration of sucrose. It is grown commercially for sugar production. In 2011 France, the United States, Germany, Russia and Ukraine were the world's five largest sugar beet producers by metric ton; by value, Turkey takes the place of Ukraine [1]. However, in 2010-2011, North America, Western Europe and Eastern Europe did not produce enough sugar from sugar beets, and were all net importers of sugar. The US harvested 1,004,600 acres (4,065 km²) of sugar beets in 2008 [2]. In 2009 sugar beets accounted for 20% of the world's sugar production [3]. The sugar beet has a conical, white, fleshy root (a taproot) with a flat crown. The plant consists of the root and a rosette of leaves. Sugar is formed through a process of photosynthesis in the leaves, and it is then stored in the root. The root of the beet contains 75% water, about 20% sugar and 5% pulp (the exact sugar contents can vary between 12 and 21% of sugar, depending on the cultivar and growing conditions) [4]. Sugar is the primary value of sugar beet as a cash crop. The pulp, insoluble in water and mainly composed of cellulose, hemicellulose, lignin, and pectin, is used in animal feed. The byproducts of the sugar beet crop, such as pulp and molasses, add another 10% to the value of the harvest [3]**.** Worldwide sugar beet production indicates that the world harvested 271.6 million metric tons of sugar beets in 2011. The world's largest producer was Russia, with a 47.6 million metric ton harvest. The average yield of sugar beet crops worldwide was 58.2 tons per hectare. The most productive sugar beet farms in the world, in 2010, were in Chile, with a nationwide average yield of 87.3 tons per hectare [5].

The north-central and western regions of the U.S. are important sugar beet-producing regions. Minnesota, Idaho, North Dakota, Nebraska, Montana, California, Wyoming, Colorado and Oregon were all among the top 10 states nationally in sugar beet production in 2011. Processing plants in these regions refine the sugar from the beets and produce large volumes of by-products, which are useful feed ingredients for beef cattle producers. Pulp that will be marketed as dry shreds or pellets is conveyed to a pulp dryer. The pulp dryer dries the pulp to approximately 10% moisture. After drying, the pulp is pelleted to facilitate storage and transportation. Molasses is produced during the refining process. The volume of molasses produced varies but is typically about 4 to 5 % of the weight of the raw sugar beets [6]. It has no Vitamin A, so additional forage or supplementation is required to provide complete nutrition. Sometimes molasses is added to improve palatability [7].

1. Importance of Sugar Beet Pulp:

Sugar beet pulp is a by-product which is obtained in technological procedure of sugar beet processing in sugar refining industry. Sugar beet pulp is primarily used as a component in final feedstuffs. In Egypt, there is a serious shortage of dietary energy ingredients needed for ruminant feeding. The animal nutrition system depends mainly on the imported grains. However, increasing quantities of sugar beet pulp are now available as a by-product from sugar beet industry. It has been estimated that there are about 135, 623 feddans cultivated annually by sugar beet, producing about 2,888,770 ton of tubers. Dried sugar beet pulp which is left-off after sugar extraction represents about 173,326 ton, the latter contribute to the local nutrient supply by 155993 ton DM, 113,150 ton TDN and 6,708 ton DCP [4].

Sugar beet pulp shreds are a co-product of the sugar beet industry and offer a valuable feed resource for all types of livestock. Sugar beet pulp shreds are the fibrous portion of the sugar beet left after the sugars are removed and is mechanically pressed and dried to reduce the water content to approximately 9%, Sugar beet pulp fiber is highly digestible, extremely palatable feed in a form that is considered less dusty than hay and the sugar beet pulp is a popular feed for ruminants [8, 9].

2. The nutrient content of sugar beet by-products:

Sugar beet pulp allows animals to be on full feed and reduces the danger of bloating and digestive disturbance. For show animals, sugar beet pulp has a cooling affect and enhances the bloom of the coat for best appearance, and when soaked in water it provides succulence in the ration. Sugar beet pulp provides a variety in feed rations, firm's stools for cleaner pen operation and allows for increased feed intake. Sugar beet pulp can be used in a variety of beef cattle diets. Sugar beet pulp contains 9.1% CP, 31% ADF, 0.72% calcium, and 0.20% phosphorus [8].

Sugar beet pulp is a highly digestible fiber source. It is sold in both wet and dry forms. The dry product contains approximately 10% moisture and has high energy in a palatable form in rumen fermentable. Similar in energy levels to barley but low average in protein. Contains highly digestible fiber which is suited to ruminants as it maintains rumen condition and encourages acetate production. It has a high liquid absorbency and can, therefore, be used as a silage additive to retain the feed value from effluent. Sugar beet pulp can be used as a source of supplemental energy in beef cow diets or as an ingredient in back grounding and finishing rations (primarily as a source of highly digestible roughage). Because of the low protein content of sugar beet pulp, supplemental protein is typically needed in most applications, especially if low-quality forages are being fed. Sugar beet pulp shreds can easily be stacked and stored. Changes in temperature are not harmful if reasonably dry conditions are maintained. Dry sugar beet pulp can be stored in flat storage (e.g., Quonsets or steel buildings). Wet sugar beet pulp should be fed within two weeks of delivery to prevent spoilage and shrink losses. However, it can be stored in silage bags as a means to prolong storage time and reduce spoilage. Sugar beet pulp has high in rumen fermentable energy (FME) in a palatable form [9].

Similar in energy levels to barley but low / average in protein. Contains highly digestible fiber which is suited to ruminants as it maintains rumen condition and encourages acetate production. It has a high liquid absorbency and can, therefore, be used as a silage additive to retain the feed value from effluent. Beet pulp can be used effectively as a supplement for gestating or lactating cows, as an ingredient in back grounding diets or as a replacement for roughage in finishing diets. Beet pulp is relatively low in CP (8%), but relatively high in TDN (72%). However, reductions in DM intake will occur at inclusions greater than 20 percent of the diet. In finishing diets, wet beet pulp can be used as the roughage source, having an energy value greater than corn silage**.** As a partial or complete roughage replacement, it can be included at 5 percent to 15 percent of the diet in finishing rations on DM basis [10].

When wet beet pulp is fed at 20% of the diet DM, cattle will consume 30 to 35 pounds of wet pulp which would be less than 1% of their body weight on DM basis. The sugar beet industry produces a wide variety of useful by-products for livestock feeders. The decision to incorporate sugar beet by-products into diets should be based on economics, local availability, and feasibility of storage, handling and feeding or the wet by-products, careful attention should be given to transportation costs and storage. In addition, rations containing sugar beet by-products should be balanced properly to achieve targeted livestock performance [10]. The ideal fiber preparation should meet several requirements among which are bland in taste, colour, texture, and odder [11]. Essentially physical treatments including cleaning, extraction, sieving, and heating have been described, although some chemical treatments have also been proposed. With special processing, it is possible to produce a dietary fiber, with an off-white colour and unobtrusive flavour, suitable for human food. The fibers may be milled to a given particle size from course to fine depending on the intended use, or treated with steam in a leaking process. Dietary fiber in sugar beet comes exclusively from its cell walls and is devoid of resistant starch or other reserve polysaccharides.

The nutrient content of a variety of sugar beet by-products is shown in **Table (1**). The chemical composition of DSBP was reported to range 83.8-92.5% for DM, 9.3-10.7% for CP, 0.1-2.4% for EE, 18.4-22% for CF, 59.3-65.7% for NFE and 3.2-6.7 for ash [12, 13, 14].

3. Sugar Beet pulp Composition:

Sugar beet pulp has a high dietary fiber content, typically >75%, and is known for its high soluble fiber content [15]. Lignin content of beet fiber is low (<5%) The remainder of the fiber preparations consists of proteins (< 10%), ash (3% to 8%) and lipids (<2%) [16]. These results show that DSBP could be used as a satisfactory source of energy with vitamin-D addition as replacement of corn grains up to 100% in the diet of ewes and fattening lambs to reduce the cost of feeding by 27.4% with 50% DSBP and 35.2% with 100% DSBP diet. Some sugar beet pulp fractions may be high in ash arising from contamination by soil particles. Composition of beet cell walls and therefore sugar beet fiber are characterized by very high pectin content, with about 20% each of galacturonic acid and arabinose [17]. Sugar beet fiber also contains approximately 20% of glucose mainly of cellulosic origin. In total, sugars account for about 80% of the dry weight with remarkably low amounts of xylose and mannose. Several non-sugar constituents are also present: methanol, acetic acid, phenolic acids, proteins, lignin, and ash**.** Few polysaccharides mainly of pectic origin are extractable from sugar beet by water in the sugar factory. This low extraction of pectin could be due to physical limitations to diffusion of the pectic polymers from the cell wall network or to the structure of beet cell walls. In sugar beet, pectin's backbone carries both methyl esters and acetyl esters on the secondary alcohols. Hemicelluloses can be defined as cell wall polysaccharides that have the capacity to bind strongly to cellulose microfibrils by hydrogen bonds. The common structural features of hemi celluloses are a main chain with a structural resemblance to cellulose and either short side chains that result in a pipe cleaner shaped molecule or a different sugar interpolated in the main chain. Beet cell walls have very low concentrations of the sugars that denote hemicelluloses [18].

4. Nutrient composition of dried sugar beet pulp:

Chemical analysis and nutrient composition of DSBP indicated that it contains 89.52% DM, 10.71% CP, 21.54% CF, and 0.64% EE, 3.25% ash, 63.86% NFE, 2.83% lignin, 0.29% reducing sugars, 2.99% sucrose, starch not detectable, 8.21% true protein, 0.77% Calcium, 0.09% Phosphorous, 0.3% Magnesium and 0.03% Iron on dry matter basis. In addition DSBP contains 0.21 mg B-carotene per kg D.M. The gross energy concentration is about 4164 Kcal/kg (17.43 MJ/Kg) and about 85% of CP was from true protein. The crude protein content of DSBP is relatively low but with high bioavailability and the true protein content ranges from 54 to 77% of the total nitrogen of DSBP [19].

The chemical composition of DSBP on DM basis was as follows: CP (8.03-11.80) %, CF (14.30-21) %; NFE (46.93-66.70) %; EE (0.1-2.4) % and ash (3.4-8.7) % [20]. The chemical composition of DSBP was reported to range 83.8-92.5% for DM, 9.3-10.7% for CP, 0.1-2.4% for EE, 18.4-22% for CF, 59.3-65.7% for NFE and 3.2-6.7 for ash **(Tables 2).**

In comparison with corn grains the CF content of DSBP is much higher and the soluble carbohydrate fraction is much lower, however, the carbohydrates of DSBP are of high digestibility and fermentibility [21]. The structural carbohydrate of DSBP is low in lignin (2-3%) and the cellulose structure is almost amorphous and easily hydrolysable [22]. The pectin's content of DSBP is high (22-35% of DM) and it is not covalently linked to a lignified matrix, which provides a readily fermentable carbohydrate source for rumen microbial biosynthesis [23]. The nutritive value of DSBP could be fairly compared with that of high-energy grains like corn, barley or oats. The TDN value of DSBP was reported to range 68-74% and the ME value was about 2.99 Mcal/Kg, (12.52 MJ/Kg DM) [24]. DSPB was high in calcium content and low in phosphorus content in comparison with corn. In addition, DSBP is high in fiber (19%) for very concentrated dietary formulations and deficient in fat, phosphorus, carotene and certain B-Vitamins [25]. Total oxalate content in leaf, root and pulp of sugar beet that were 4.9 g/100g DM, 366.5 and 236.9 mg/100 DM, respectively [26]. Total oxalate of sugar beet tops on DM basis was ranged between 3.3 and 4.89% and oxalic acid can inhibit the absorption of calcium because calcium is insoluble [27]. High oxalic and levels led to lower appetence for feed with stress symptoms and other biochemical, clinical and histological findings. Whole beets can be fed successfully to cattle and although whole beets are low in crude protein (6.8-8.0 %) but high in energy (75 to 81% TDN). Whole sugar beets also can be fed by chopping in a tub grinder or forage harvester to reduce the risk of choking. Whole sugar beets can be chopped and ensiled as a storage method [28].

Ontario sugar beet crop is an exceptional crop with yields much better than expected; resulting in more beets than can be reasonably processed. Sugar beet producers are being encouraged to consider a Set Aside Program option. A portion of the crop would be left un harvested or undelivered for processing. Those who are planning to participate in the Set Aside Program may be looking for alternatives such as harvesting the whole beets for use as a livestock feed. Several livestock producers may have had experience with feeding the by-product of sugar beet processing - moist beet pulp, but not with feeding whole sugar beets. The whole beets' sugar content and their digestible fibre make them a good source of energy and have been successfully used in feeding ruminants, such as cattle and sheep. The feeding value of sugar beets could be considered similar to corn and cob meal with equivalent energy levels but with slightly lower protein than corn and cob meal [30]. The typical nutritional analysis of whole sugar beets to beet pulp, corn silage, corn and cob meal and shelled corn on a dry matter basis are shown in **Table (3)** of Ministry of Agriculture and food [29]. Considerations when feeding whole sugar beets according to Ministry of Agriculture and food are in the following:

1. The high moisture levels (approximately 80%) and relatively high sugar content of whole beets can present storage challenges.
2. Industry consultants are suggesting unprocessed sugar beets may be stored in a pile with minimal spoilage until well into February. However, piled beets must be used up prior to warm weather in mid March as warm temperatures will cause rapid decay and significant nuisance insect problems will develop.
3. Ensiling processed sugar beets in combination with a dry ingredient such as straw, hay or corn stalks to achieve a final moisture level of 35-40% can be a longer term storage option. The pile should be packed and covered to exclude oxygen.
4. The location of temporary storage piles should be considered carefully in order to minimize the potential for environmental contamination and offensive smells. Monitor and prevent any potential runoff from reaching surface water bodies like streams, ditches and ponds.
5. Mixing processed sugar beets with straw at a ratio of four or five beets to one of straw has been shown to be an effective ensiling mixture.
6. The sugar content of beets provides an excellent source of fermentable carbohydrate needed for successful fermentation.
7. Whole beets can be processed by various methods such as feeding them through a forage harvester; in a

tub grinder; extended agitation in TMR mixer; driving over them or putting them through an industrial wood chipper.

8. Cattle and sheep can consume unprocessed whole sugar beets. To reduce the risk of smaller beets becoming lodged in animal's throats and to facilitate a more uniform mixing with other ingredients it is recommended that sugar beets be broken or processed prior to feeding.
9. Suggested ration inclusion rates are up to 20% of the dry matter intake for back grounding/ growing cattle and up to 50% of a beef cow's dry matter intake.
10. The beet tops can also be fed but because the majority of the feed value is contained within the beet, it may be better to focus efforts on preserving and utilizing the beet itself.
11. It is important to determine which fungicide and herbicide was used with the sugar beet crop as there may be label restrictions regarding the use of sugar beets as a feed ingredient.

5. Sugar beet pulp as energy source for ruminants:

Sugar beet pulp could be used as a satisfactory source of energy in rations for growing and fattening ruminants

DSBP could be incorporated in lambs finishing rations and replace up to 50% of energy sources [20]. Moreover, Lambs fed on DSBP ration were heavier than those fed the traditional control rations [26]. The DSBP could partially replace the traditional concentrate mixture up to 50% [30]. DSBP energy was as well utilized as corn or barley up to 60% in concentrate rations for ruminants [25]. Replacing the concentrated ration up to 25% by DSBP in buffalo diets resulted in an increase in CF, ADF and NDF content of the daily ration which were (21.76-21.27) %, (28.54-28.02) % and (49.61-48.46) % for summer and winter diets, respectively [31]. Feeding DSBP did not show any negative effects on daily milk yield, daily corrected fat milk (4% CFM) and chemical composition of the milk but DM, starch value and net starch value rate of conversions to milk were not affected significantly by receiving DSBP [32]. DSBP is similar to corn as a source of energy for lactating cows up to 73% in a well balanced dairy concentrate ration [33]. DSBP when corrected for its deficiencies could be used successfully as a grain replacement by weight, even at high levels in complete rations for dairy cattle and sheep. Although slightly less in theoretical TDN content as compared to corn or barley, beet pulp, by virtue of its 20% highly digestible fiber content, imparts the desired physical fitness to the ration making the dietary energy available to the fullest extent. Moreover, by-product nature of the feedstuff and its comparative low price have made beet pulp an attractive ingredient in livestock rations [34].

Figure 1 Sugar beet pulp in the field.

Figure 2 Harvest Sugar beet pulp in the field

Figure 3 Sugar beet pulp tubers and extracted Sugar.

Figure 4 Shreds, pellets and crumbles of sugar beet pulp.

6- Effect of sugar beet pulp on animal performance:

1-Feed Intake

DSBP tends to increase DM intake from 1.34 to 1.43 and 1.64 kg/h/d with 0.0, 17.13 and 34.25% DSBP supplemented rations, respectively [22]. DSBP contains high level of water-soluble carbohydrate so, this product tends to increase total DM intake [35]. The feed intake increased by increasing DSBP level in the ration [36]. DM intake for cows feed beet pulp was lower than DM intake of cows fed corn. Cows fed beet pulp consumed DM at 3.69% of BW, whereas those eating corn consumed 3.97% of BW. Lower DM intake of cows fed beet pulp resulted in concomitant increased ADF and NDF intakes and efficiency of feed utilization was markedly improved in cows fed beet pulp as compared with those given corn [37].

2-Digestibility and nutrient utilization:

DSBP is high readily digested crude fiber 20% which imparts certain physical and chemical characteristics to rumen ingests for avoiding digestive problems, acidosis and depressed appetite [38]. CF digestibility increased significantly with increase the DSBP in the ration [34]. The high feeding value of DSBP was partly due to its highly digestible fiber and consequently high-energy contents [39]. The digestibility of EE was lower and the digestibility of CF was higher with increasing beet pulp in the ration [40]. CF content of DSBP could be digested as efficiently as nitrogen free extract fraction when included in rations of Holstein cows [37]. The digestibility coefficients of DM and NFE were unaffected by replacement of yellow corn by DSBP. Even though, the digestibility of CF was significantly high and the digestibility of EE was significantly lower when yellow corn was replaced by either 50% or 100% DSBP [28]. CF of beet pulp was high digestible and ration digestibility increased at each increase in beet pulp dietary content [41].Moreover, degradability of DM, NDF, ADF and hemicelluloses were significantly increased by supplementation of 10% DSBP to Italian ryegrass hay used in feeding fistulated goats [42]. The digestibility of EE was significantly lower and that of DM, OM, CP and CF were significantly higher with ration contained DSBP than control [30]. CF was increased with the increase of DSBP in the ration of lambs. The same authors reported that NFE digestibility did not show any significant difference among ration containing different levels of beet pulp [20]. The attractive increase of N% utilization was with diets containing 25 or 50% DSBP [37]. Utilization of dietary nitrogen had been improved by sheep and goats with feeding rations containing 50% DSBP [30]. The fermentation of DSBP enhanced its nutritive value by increasing its protein content whereas DSBP potentially good source of dietary protein in the ruminant diets [43]. On the other hand, digestibility of DM, NFE and CP did not show any significant difference among the three rations containing 0, 17.13 and 34.25% DSBP [20]. CP digestibility decreased by increasing DSBP level [28]. Mousa [44] evaluated the effect of feeding different levels of fodder beet roots in replacement of CFM on the nutritive values, productive performance and economical efficiency of ewes and dairy goats. Four rations were evaluated during the first. The control ration consisted of CFM and rice straw. Three tested rations were formulated so that 35, 50 and 65% of CFM were replaced by fodder beet roots. In the second trial, ration 3 which showed the highest feeding value and had the highest possible replacement without negative effects was compared with the control ration in a feeding trial. Digestibility coefficients of dry matter, organic matter, ether extract and nitrogen free extract were not significantly affected by any level of replacement while the digestibility of crude protein and crude fiber were significantly decreased as the fodder beet roots in diets increased. The same trend was recorded for Digestible Crude Protein and all animals were in positive N-balance. There were no significant effects on birth weight, weaning weight and daily weight gain of kids or lambs due to feeding their dams on fodder beet. Dairy goats and ewes fed on fodder beet roots produced more milk than the control by about 12.09 and 24.38%, respectively. Therefore, replacement of fodder beet roots up to 50% from CFM in dairy goats and ewes diets improved milk yield, productive performance, economical efficiency, decreased feed cost and can participate in solving the problem of feed stuffs shortage in North Sinai.

3-Rumen Fermentation

The rumen microorganisms increase when DSBP is added to the diet for dairy cows [22]. Total nitrogen and amino acids in duodenal digesta were increased mainly as a result of improved bacterial protein synthesis in the rumen when DSBP was used in the rations of non-pregnant Friesian heifers [45]. Moreover, the total VFA's concentration significantly increased as the proportion of DSBP increased in the ration [30]. Total VFA's concentrations have significantly increased as the proportion of dietary DSBP was increased in the ration but ruminal pH values and NH_3-N concentration were unaffected [28]. Similarly when yellow corn was replaced by DSBP in the ration of goats, the reuminal pH values and NH_3-N concentration not significantly altered [46]. When the proportion of beet pulp in the rations increased to replace corn, the concentration of VFA's significantly increased even though, the ruminal pH values were not affected [47].

No significant differences in rumen pH values were detected between Rahmani rams consuming rations containing different levels of DSBP (0,25 and 50%) as replacement of concentrate mixture, while the concentration of total VFA's and NH_3-N significantly increased [41]. Ruminal NH_3-N concentration was higher with rations containing the higher proportion level of DSBP [48]. Total or proportional VFA's concentrations were not found to be influenced by changing the carbohydrate source from starch grains to DSBP [49, 50]. Lower propionate and branched chain VFA's were observed in the rumen liquor of lactating cows fed beet pulp diets instead of corn [23]. Increased production of rumen VFA's and a less frothy rumen ingesta when beet pulp replaced corn in the high concentrate dairy ration [34]. Butyric acid in rumen fluid increased and ammonia concentration was reduced by incorporating DSBP in the ration [45].

4-Daily Body Weight Gain

Digestibility trials with 8 lots of pelleted dried SBP, carried out with withers, and demonstrated that dried sugar beet pulp is a highly digestible energy source for ruminants. From the digestion coefficients obtained, and a value number of 95, the starch equivalent of the DM of DSBP was calculated to be 73.3, while the net energy was 619 per kg DM. This is about 90% of the net energy content of barley containing 4% CF in the DM. Beef production trials were carried out with 702 young bulls fed on complete dry rations based on dried sugar beet pulp. Two categories of animals were used: 322 baby-beef bulls slaughtered at 13 months of age at an average live-weight of 480 kg; and 380 young bulls coming from pasture at about 250 kg live-weight, and fattened indoors up to at least 550 kg live-weight. With each category, three different rations have been studied. These contained respectively, 50, 60 or 70% pelleted dried sugar beet pulp; the remainder of the rations consisted of respectively 50, 40 or 30% concentrates. The diets were fed *ad libitum*; straw and water were always available. The three complete dry rations proved to be equally successful for intensive beef production. The carcass quality was good for all animals. The average daily gain obtained with the baby-beef bulls for the three rations respectively was 1207 g, 1274 g and 1172 g; for the second category of bulls the mean growth rates were generally slightly higher: 1281 g, 1309 g and 1357 g. The feed efficiency was higher with the younger animals: the baby-beef bulls (live-weight interval: 150–480 kg) consumed about 2.5 kg protein supplement and 3.5 kg DSBP per kg live-weight gain; while the intake per kg live-weight gain with the bulls of the second category (live-weight interval: 250–560 kg) amounted approximately to 2.75 kg protein supplement and 4 kg DSBP. Within each category of bulls, the feed cost per kg live-weight gain decreased with increasing amounts of DSBP in the rations [51]. The averages DBG in Ossimi lambs given concentrate feed mixture in which 50 or 100% of energy requirements for growth was replaced by DSBP were 95.9, 99.6 and 64.8g, respectively [52]. The average daily gain of the sheep fed ground ration containing corn was significantly lower than that of those fed beet pulp or beet pulp plus corn as sole source of energy in their rations. The averages BWG values were 80, 110 and 130g while feed conversion values were 12.0, 8.8 and 8.1 kg feed/kg gain, respectively [53]. The average DBG of Barki lambs fed rations containing 17.3 and 34.25% DSBP were higher (162 and 164g, respectively) than those fed the control ration (140g daily gain) which had 0.0% DSBP but the average feed conversion decreased by increasing the proportion of DSBP in the ration [20]. Average BWG increased while the feed conversion decreased when the proportion of DSBP was increased from 0.0% in the control ration to 25 or 50% in the other experimental ration [41]. Sheep fed 3% untreated-sugar beet pulp (USBP) at 50% replacement had the highest average daily gain, while the lowest weight gain was obtained with sheep fed 100% USBP ration mainly due to lower feed intake. [54]. The same authors reported that inclusion of USBP at 50% level to replace common fed mixture had significantly increased BWG of sheep by nearly 30% in comparison with the control ration (188.5 vs. 145.4g/d) and the feed conversion either as DM/kg or TDN/kg gain were significantly improved with the ration containing 50% USBP in comparison with control but feed conversion was significantly deteriorated with feeding concentrate ration of 100% USBP. The same trend was observed in growing fattening sheep fed on diet contained 45% DSBP + 45% corn grained faster and required less feed per unit of gain than those fed on either 90% corn or 90% DSBP [53]. Feeding on complete dry diets contained 50% DSBP fed according to appetite resulted in high animal performance and high feed efficiency of young bulls [51].

Any limitation in growth performance by lambs fed a diet containing 100% molasses-SBP may be effectively abolished by the replacement with barley at a substitution rate of 25% or greater [24]. Average BWG was higher in the SBP fed groups and indicated that the lamb's growth rates during the finishing stage were 189.4, 226.5 and 216.2 g/h/d for control, 50% and 100% DSBP diets, respectively, and that partial (50%) or complete replacement of dietary corn as an energy source by DSBP had a significant better influence on lambs daily growth rates and concluded that diets containing 1:1 corn and DSBP gave better growth rate than those containing only corn or DSBP [26]. Replacement concentrate feed mixture by sugar beet pulp supplemented with 10% soybean meal can be recommended for rations of growing sheep with no adverse effect on their performance, digestion processes, carcass characteristics and blood constituents [14]. Also, incorporation of SBP in sheep ration could lead to formulate cheap rations and consequently decreased the feeding cost. As with any ensiling process, good silage-making principles should be employed. Beet pulp can be used effectively as a supplement for gestating or lactating cows, as an ingredient in back grounding diets or as a replacement for roughage in finishing diets [6]. Research conducted at NDSU indicates that wet BP can be included at up to 40 percent of the diet (DM, basis) in back grounding diets (Table 4).

However, reductions in DM intake will occur at inclusions greater than 20 percent of the diet, used as the roughage source, having an energy value greater than corn silage [55] (Table 5)

Table 1 Typical Analysis of dried sugar beet pulp [12].

Dry Matter	90.0	Starch	2.0
Crude Protein	11.0	Sugar	23.0
DCP	7.2	Calcium	0.95
ME	12.5	Potassium	2.0
Crude Fiber	15.0	Total Phosphorus	0.15
EE	0.4	Sodium	0.5
Ash	8.5	Magnesium	0.15

Table 2 Nutrient composition of various sugar beet by-products on DM basis [20].

Feed stuff	DM	CP	TDN	NE for maintenance	NE for gain	ADF	Ca	p
Sugar beet tops	17.0	15.1	58.0	0.59	0.27	14.0	1.01	0.22
Sugar beet top silage	21.0	12.7	53.0	0.55	0.20	18.0	1.56	0.20
Sugar beet tailings	18.4	8.9	65.0	0.67	0.40	34.0	2.35	0.27
Sugar beet talling silage	20.0	10.0	65.0	0.66	0.40	0.0	2.5	0.20
Sugar beet top silage	32.0	11.9	51.0	0.45	0.20	0.0	1.56	0.22
Sugar beet pulp, dried	90.0	9.1	72.0	0.77	0.49	0.31	0.72	0.20
Sugar beet pulp, wet	25.1	9.1	72.0	0.77	0.49	0.31	0.72	0.20
Sugar beet whole	20.1	6.8	81.0	0.90	0.60	0.0	0.24	0.24
Sugar beet molasses	77.0	10.0	75.0	0.77	0.50	0.0	0.12	0.03
Concentrated separator by-product (CSP)	66.0	20.0	67.0	0.75	0.42	0.0	0.05	0.03

Table 3 Nutritional analysis of whole sugar beets, sugar beet pulp, corn silage, corn and cob meal and shelled corn on dry matter basis% [29].

Items	DM	CP	TDN	Ca	P
Whole Sugar Beets	20	6.8	81	0.24	0.24
Sugar Beet Pulp (moist)	25	9.0	72	0.72	0.20
Corn and Cob Meal	87	9.0	82	0.10	0.24
Corn Silage	35	8.0	69	0.30	0.20
Shelled Corn	87	9.5	88	0.01	0.30

Table 4 Complete analysis of sugar beet pulp (NDSU)

Protein%	12.7	Vit. K mg/kg	4	Iron mg/kg	20
Oil%	9.7	Vit. C mg/kg	16	Copper mg/kg	40
Fibre%	21	Vit. B_1 mg/kg	80	Mn mg/kg	50
Starch%	8	Vit. B_2 mg/kg	24	Zinc mg/kg	80
Sugar%	3	Vit. B_{12} mg/kg	0.1	Se mg/kg	0.4
DE MJ/kg	11.5	Vit. B_6 mg/kg	24	Iodine mg/kg	0.8
Ca%	0.9	Niacin mg/kg	100	Choline mg/kg	40
P%	0.4	Folic acid mg/kg	40	Lysine g/kg	4
Vit. A IU/kg	1600	Boitin mg/kg	6	Methionine g/kg	1
Vit. D3 IU/kg	1200	Mg g/kg	1.2	Brewers g/kg yeast	2
Vit. E mg/kg	400				

Table 5 Effect of increasing level of pressed beet pulp (BP) and concentrated separator by-product (CSP) in back grounding rations on performance of steer calves [55].

Performance	Ratios between pressed BP to CSP inclusion (% of ration DM)					
	0:0	20:0	40:0	0:10	20:10	40:10
ADG, lbs	3.98	3.39	3.12	3.67	3.50	3.17
DMI, lb/day	21.45	19.16	17.56	22.46	20.55	18.77
F:G	5.41	5.65	5.65	6.06	0.01	5.92
Apparent dietary NE, Mcal/ lb						
Maintenance	0.91	0.89	0.90	0.89	0.86	0.86
Gain	0.61	0.59	0.60	0.54	0.59	0.57
Performance	Ratios between pressed BP to CSP inclusion (% of ration DM)					
	5:0	12.5:0	20:0	5:10	12.5:10	20:10
ADG, lbs	3.78	3.67	3.30	3.87	3.74	3.32
DMI, lb/day	24.16	24.16	22.66	25.54	26.05	24.20
F:G	6.37	6.58	6.85	6.58	6.94	7.30
Apparent dietary NE, Mcal/ lb						
Maintenance	1.0	0.99	0.97	1.0	0.99	0.92
Gain	0.70	0.68	0.67	0.69	0.68	0.62

5-Milk Yield and Composition

Pressed BP contains 20 - 25% DM, limiting the distance it can be transported economically. Nevertheless, pressed BP is a valuable feed high in energy (85% of the energy value of corn), and low in protein (7–10% crude protein). Pressed BP is considered a non forage fiber source and may be used to partially replace forage in dairy cattle rations at a rate of 10 to 20% of the ration DM. Higher levels may reduce dry matter intake. According to Utah State University research, dairy cattle fed a total mixed ration with either pressed beet pulp or dried beet pulp exhibited no difference in milk yield or composition. A recent University of Idaho study compared total mixed rations with and without pressed BP on a commercial dairy. Pressed BP replaced corn silage in the test total mixed ration. Milk yield and composition data are currently being analysed [25, 38]. Two experiments evaluated the effect on milk yield and composition of including sodium bicarbonate in the barley supplement or feeding dried molasses BP to January-March calving cows after turn out to pasture. In both experiments, supplements were offered at a level of 5.4 kg/cow per day. In Experiment 1, including 46 g/kg sodium bicarbonate in a barley supplement did not change milk yield or composition in comparison with a barley supplement without sodium bicarbonate. Feeding a dried molasses BP supplement increased milk yield ($p < 0.05$), fat concentration ($p < 0.05$) and fat yield ($p < 0.01$) compared with the barley supplement. In Experiment 2, milk yields and composition were similar on dried molasses BP based supplements, with (50 g/kg) and without sodium bicarbonate [56]. Milk production was not affected by incorporating beet pulp in control concentrates (at the rate of 15.5%) of the diet of Holstein cows [57]. Average daily milk yield and daily Fat-corrected milk (FCM) (4%) was not affected significantly by incorporating DSBP into the concentrate at the rate of 12.5 and 25% level in the ration of lactating buffaloes [32]. Daily MY and milk fat content were significantly increased in cows fed the concentrate mixtures containing 25 and 40% DSBP in comparison with the control ration. The same authors found that the average daily of 4% FCM was increased by 7.15% and 11.90% and the feed cost per ton was decreased by 13.4% and 16.9% for cows fed the concentrate mixtures containing 25 or 40% DSBP, respectively [54]. Daily milk yield and milk fat content were significantly increased in ewes fed the concentrate mixtures containing 27 and 54% DSBP in comparison with the control ration [58]. Dairy cows fed DSBP had higher milk fat content in comparison with those fed corn or barley grains rations, (3.64vs. 4.49%) [59]. Sugar beet pulp has positive effect on milk production, especially, during the first 8 to 10 weeks of lactation for dairy cows [21]. Mansfield et al. [38] studied the effect of carbohydrate source (ground corn vs. DSBP) on performance of Holstein cows (during week 4 to 17 week of lactation). Dried SBP replaced half the corn which represented about 15% of dietary DM. Diet DM contained 18% alfalfa pellets, 17.4% alfalfa hay, 17.2% corn silage and 47.1 concentrated mixtures. The same authors reported that neither MY (32.0 kg/d) nor FCM 3.5% were affected by DSBP replacement. In addition, milk solids-not-fat and lactose percentages were not affected by DSBP supplementation. Milk CP percentage and milk CP yields decreased by 3.7 and 5.28%, respectively, but milk fat percentage increased by 4.7% when beet pulp replaced corn. Petit and Tremblay [60, 61] fed Holstein cows between week 4 and 15 lactation on grass silage for *ad libitum* intake with concentrated supplement containing soybean meal fed with corn (SBCO) or SBBP and found that MY was similar among treatments but 4% FCM was higher by 3.5kg/d for cows fed SBBP than those given SBCO supplemented. In addition, milk fat and protein were higher for cows fed SBBP than those fed SBCO and milk efficiency, as kg of FCM per kg of DMI was higher for fed beet pulp than for those fed corn grains and feed efficiency for milk production (kg diet/kg milk) was not affected by the dietary treatments. Huhtanen [62] fed cows on silage to appetite with 1kg rapeseed oil meal and 6kg of an energy supplement consisting of rolled barley or sugar beet pulp with or without 1.96 beet molasses or barley and pulp (1:1) with 0.98kg molasses and found that for barley, barley/molasses, barley/pulp, pulp and pulp/molasses diets respectively, daily MY averaged 23.2, 21.9, 24.0, 24.4 and 23.0 kg with fat 49.1, 49.0, 48.2, 45.5 and 46.4 g/kg. Yield of milk and protein were higher with pulp than with barley supplement and energy conversion to milk, ignoring live weight change, was highest with the barley/pulp supplement and higher with pulp than with barley supplements. El-Ashry et al. [31] found that mean daily milk yield tended to decrease while 4% FCM yield (kg/d) tended to increase with the increase of DSBP in buffalo rations. O'mara et al. [47] found that milk protein was higher when cows fed on concentrate were based on beet pulp than those fed concentrate based on corn of wheat. Beauchemin et al. [57] showed that milk fat was increased by incorporating dried sugar beet pulp pellets into the concentrate (15.5% level) may be due to increase NDF content from 29 to 32% in the diet of Holstein cows. Fat content of milk increased for cows fed DSBP as a replacement for grain due to higher fiber intake and greater acetate concentration in the rumen [63]. Lactose and SNF percentage was not affected by feeding DSBP in comparison with ground corn as sources of carbohydrate in the rations of Holstein cows [37]. El-Ashry et al. [31] explained the increase in total solids of milk for buffalo fed DSBP to be due to the increase of fat and protein percentages.

In a single changeover trial, two paired groups of 21 cows were fed on grass silage, concentrates and 5 kg DM as un-molasses SBP. The last named provided about one-third of total DM intake. Milk yield and composition were not affected by giving the pulp fresh (201 g DM/ kg) rather than dried. In a second, similar experiment with two paired groups of 16 cows, 5 kg DM matter given as un-molasses pressed SBP gave a significantly ($P<0.001$) higher milk yield (+0.8kg/ day) and significantly ($P < 0.001$) lower milk fat content (−1.7 g/kg) than 5 kg DM given as molasses pressed SBP containing 40% of beet molasses. The total amounts of fat produced per day were unaffected by diet. Although the protein in dried un-molasses SBP was of very low degradability in the rumen, this did not affect the yield or protein content of the milk [67, 68].

6- Blood parameters, animal health and economic efficiency

Blood glucose and total proteins did not show any significant changes due to replacing corn with beet pulp [34]. Blood glucose and total VFA's tended to increase with the increase in the proportion of beet pulp in the diet suggesting efficient rumen utilization of the beet pulp [25].No significant differences in total erythrocytes count and total leukocyte count in the blood of buffalo's calves fed different diets containing different levels of DSBP [64]. Buffaloes groups fed DSBP had higher values of serum total proteins, albumin, globulin and urea than the control group whereas, GOT and GPT enzymatic activity of the control groups were higher than the groups that fed were dried sugar beet pulp [32]. In mature Rahmani rams, there were no significant diet effects on packed cell volume, haemoglobin, activity of GPT, Mg and Na concentrations [28]. Serum urea concentration tended to be lower for Holstein cows fed beet pulp than for those fed starch as the energy source [60, 61]. Plasma proteins, albumin, globulin, glucose and urea nitrogen did not show any significant changes due to replacing yellow corn with DSBP and the values were within the normal ranges of sheep blood [28]. When dried molasses SBP was replaced by ground maize at level of 14% in the diet of dairy cows, blood glucose, total proteins, albumin, urea, triglycerides, cholesterol, Na, K, P and Mg were not affected [65]. Blood parameters of Rahmani rams were not affected by the addition of DSBP to the rations except of urea-N which significantly increased in the blood of rams fed rations containing 0.2 and 4% urea in comparison with the control ration [41].

CONCLUSION

The sugar-beet crop, when harvested and processed for the production of sugar, yield a number of by-products which can be used as animal feeding stuffs. Once the roots are harvested, the tops alone or the tops plus the crowns can provide a useful supply of forage for ruminant animals. The processing of sugar-beet roots results in the production of two more valuable feeds: sugar-beet pulp and molasses. The latter may be further processed by fermentation to alcohol to yield another potential feed condensed molasses soluble. These products may be used separately or combined and they may be dried or otherwise processed in a variety of ways to produce a range of high-quality animal feeds.

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