Sustainability of agricultural systems through protein supplementation of low quality forages

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Abstract

In agricultural systems where land is used alternatively for wheat-soybean production and cow-calf operations, great amounts of wheat straw are available for ruminant nutrition. As a sole feed, wheat straw provokes severe body weight losses of pregnant cows during the breeding season. Whole soybean grain which is available at the farm level, could be used as a protein supplement for improving wheat straw utilization. The objective of this study was to evaluate the effect of ground small seeds of soybean (GSS) and urea on average daily liveweight gain (ADG) of heifers fed wheat straw. During a 68 days period, twenty-two Angus heifers with 280 kg initial liveweight, were divided into two groups and were confined into stockyards of one hectare each. In GSU treatment, heifers consumed baled wheat straw (3.8% crude protein, CP) on ad libitum basis and received twice a day a supplement (2.2 kg/head, free choice). The supplement contained corn grain (73.20%), GSS (20.95%) and urea (2.18%). In the GS treatment heifers received corn grain (42.10%) and GSS (54.20%). The experiment included a non-supplemented treatment, NS, where another eleven heifers grazed mature lovegrass pasture (Eragrostis curvula) (4% CP and 70% neutral detergent fiber, NDF). This forage has a nutritive value similar to wheat straw. In the other two treatments, GS and GSU supplements contained 20.7 and 19.4% CP, respectively, 1.0% calcium and 0.8% phosphorus. ADG were 70, 426 and 639 g/d for NS, GSU and GS treatments, respectively. It is concluded that whole soybean seed and urea improves ADG of heifers fed wheat straw. Higher energy content and higher concentration of preformed amino acids could account for better ADG in the GS diet compared to GSU diet.
1 Introduction

Agricultural land in Argentina is mainly devoted to crop production and cattle breeding in mixed operations. A pastoral approach in this production system assured certain conditions of sustainability for native ecosystems along the past century. However, due to intensive crop production soil fertility has been decreasing as well as the availability of nitrogen in soils and animal diets. Argentina breeds over $7 \times 10^6$ cows for beef and dairy production mostly over moderate to low quality introduced pastures and rangeland. Because of favorable climatic conditions livestock can be raised outdoors yearlong. Under such conditions, annual calf crop is about 67%. This figure denotes low calving efficiency of calf crop which can be mainly attributed to nutritional and health factors. Argentina is being successful with a current program to eradicate livestock endemic diseases such as foot and mouth disease and brucelosis. Nutritional limitations to the diet includes protein, energy and essential minerals shortages mainly during breeding season.

More than half of all absolutely dry matter in the global harvest is in cereal and legume straws, in tops, stalks, leaves, and shoots of tuber, oil, sugar, and vegetable crops. Cereal stem, leaf, and sheath material accounts for two-thirds of all residual phytomass. This feed resource creates additional potential for livestock production, especially in areas where grain production is a major enterprise.

Argentina grows about 9.3 million hectares of cereal crops per year, and with 1,500 kg/ha of straw means 14 million Tn of straw as a residue. The cereal straw is fed to animals with moderate nutritional requirements in the traditional stubble-grazing of harvested grain fields.

Cereal straws are rich in structural carbohydrates and hence potentially a cheap source of energy for ruminant animals. Ruminants can digest cellulose because microorganisms in the rumen produce the needed enzymes (Van Soest [39]); indeed, to maintain normal rumen activity, at least one-seventh of the normal ruminant diet should be in roughage (NRC [25]). But the presence of lignin decreases the overall digestibility of residues; moreover, in addition to their low metabolizable energy, they are also low in protein and deficient in minerals (Jung et al [22], Smil [34]). Besides a more efficient use of the straw is obtained when it constitute the main proportion of the diet. As straw is a limited nutritional resource we can expect low to moderate levels of production from it.

Combination of cereal straw and such protein-rich food-processing wastes as oil cakes can replace hay or silage, making it possible to feed beef or dairy cattle without devoting farmland to concentrate and roughage crops. The cost of the components included in the supplements have limited in Argentina the utilization of supplements of low quality forage resources as compared to other countries (United States, Australia, France).

Supplementation, especially during periods of physiological stress, may offer production advantages. Without supplementation, cattle fed low-quality diets are unable to meet their nutritional needs and consequently may manifest...
symptoms of poor nutrition in terms of impaired reproductive performance, such as low conception rates, delayed estrus and puberty, poor milking, and reduced resistance to stress and disease.

One of the frequently reported benefits of feeding supplemental protein to ruminants eating low-quality forage is an improved ruminal N status (McCollum & Galyean [28], Del Curto et al [8]). Horn and McCollum [20] reported that, although ruminants consuming low-quality forages may be deficient in energy, typically the nutrient that is first-limiting to ruminal microbial fermentation is NH₃ N. Protein provided in these supplements likely alleviated an NH₃ N deficiency and thereby promoted increases in dry matter (DM) digestibility.

In ruminants that graze dormant or low-quality forage, protein is considered the first-limiting nutrient. Low NH₃ N concentrations in the rumen decreased microbial growth (Satter and Slyter [33]) and reduced the rate of fiber digestion and, consequently, reduced intake. Supplementing protein to cattle that is consuming low-quality forage has been shown to increase dry matter digestibility (Guthrie and Wagner [15]), ruminal fiber digestion (Beaty et al [3]), and protein flow too the small intestine (Hannah et al [16]).

Microbes present in the rumen have the ability to convert nonprotein N into microbial crude protein, which the animal can absorb from the small intestine. The nonprotein N will only be converted into microbial crude protein if other nutrients required by the microbes are available in sufficient quantities.

Supplementing with nonprotein N usually only reduces the rate of loss in weight, converting a submaintenance diet to, at best, a maintenance diet. Further improvement in production can only be obtained by feeding a natural protein, which is only slowly degraded by the rumen microbes and bypasses the rumen (Chalupa [6]).

The gross energy content of wheat straw is approximately 18.1 MJ/kg DM (Givens et al [13]) and is similar to that observed in other forages. The extent to which the animal can utilize this energy is dependent primarily on the extent of straw cell wall degradation, which takes place in the rumen, although further fermentation of cell walls may take place in the caecum and colon.

Increase energy demand due to physiological status, environmental stress or inadequate forage supply, however may need energy supplementation (NRC [25]).

Depressive effects of starch supplementation on cell wall digestion were found by many authors (Stewart et al [36], Henning et al [19], Dixon [10], Chase and Hibberd [17], Stritzler et al [37]). But the supplementation with limited amounts of nonstructural carbohydrate may stimulate fiber digestion by increasing microbial activity and synthesis of bacterial glycocalyces for attachment to fibrous digesta (Demeyer [9]).

El-Shazly et al [12] proposed that amylolytic microorganisms grow faster in the rumen than do cellulolytic microorganisms, which results in a competitive advantage for amylolytic over cellulolytic in the use of certain nutrients. The introduction of significant quantities of readily fermentable carbohydrate into a N-deficient ruminal ecosystem likely would faster competition between amylolytic and cellulolytic microorganisms for a limited N supply. Given the
competitive advantage of amylolytic microorganisms, significant use of N to support amylolytic microorganism growth would be expected (Olson et al [26]).

During the last few years, land under soybean cultivation has increased in Argentina. This expansion, which in part occupy marginal lands, has been promoted by the low prices of another traditional commodities such as wheat and sunflower grains. Because of that expansion availability of soybean seed at the farm level has increased in the marginal areas of crop cultivation. Then, farmers dispose of soybean seed as a nitrogen supplement for cattle, avoiding freight and other costs included when supplement need to be purchased. Whole soybean seed coming from the proper farm is though to be a reliable nitrogen source for beef cattle. Recently, soybean seed has been recognized as an energy and nitrogen supplement for high requirement dairy cattle.

Due to better prices of crops compared to livestock products there was a replacement of cattle raising from humid and subhumid to marginal regions, mainly semiarid areas. In general, semiarid areas are grazed because they are not sufficiently productive or reliable to be cropped, which means that management must cope with low or unreliable production, complex semi-natural systems, large management units, and greater economic risk.

Damage to soil and plants in arid and semiarid areas is not easily repaired (Milton et al [24]). It is therefore important to understand how surface disturbance, especially vegetation removal, affects soil quality and to increase the knowledge of the mechanisms of soil degradation processes, so that environmental problems can be adequately predicted and corrected. Unfortunately, human disturbance of sensitive areas often still goes unchecked. (Albaladejo et al [2]).

The rangelands in the low potential areas are the most vulnerable to the negative consequences of an increasing livestock population (e.g. depletion of vegetative cover, soil erosion). Through overgrazing, followed by soil erosion, increased exposure of the soil to wind and rain, this could lead into a downward transition to a stable state of much lower productivity.

Environmental management in such regions must provide economically realistic alternatives to unrestricted resource over-exploitation, while increasing human well-being and enhancing biodiversity.

The tasks, as well as the approaches to be used to ensure sustainable production of rangeland resources for the present and the future generations are not easy to devise and require a highly sophisticated level of organization and commitment (Squires et al [35]).

Sustainable agricultural practices, which are not of immediate financial benefit to the farmer are difficult to market under conditions where long-term advantages are uncertain (Heitschmidt and Walker [17]).

The objective of this study was to evaluate the effect of ground small seeds of soybean (GSS) and urea as N supplement on average daily liveweight gain of beef heifers fed whole-wheat straw.
2 Material and methods

2.1 Treatments

Experimental treatments were: (1) Non supplemented (NS). Heifers (n=11) grazed a mature lovegrass pasture (*Eragrostis curvula* [Schrad.] Nees) without supplementation. Free access to a mixture of NaCl and bonemeal was allowed. (2) GSU. Heifers (n=11) were kept in a yard (100 × 100 m) and received twice a day the GSU supplement. (3) GS. Heifers (n=11) were kept in a contiguous yard of similar dimensions and received the GS supplement. In both treatments heifers received 2.2 kg/head, free choice, daily).

Ground soybean seed was mixed with the other ingredients (Table 1) of the supplements.

<table>
<thead>
<tr>
<th>Supplement</th>
<th>GSU</th>
<th>GS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>73.20</td>
<td>42.10</td>
</tr>
<tr>
<td>Ground soybean seed</td>
<td>20.95</td>
<td>54.20</td>
</tr>
<tr>
<td>Urea</td>
<td>2.18</td>
<td>0.00</td>
</tr>
<tr>
<td>Bone meal</td>
<td>2.73</td>
<td>2.76</td>
</tr>
<tr>
<td>NaCl</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>Trace mineralized salt</td>
<td>0.27</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Supplements were formulated and pelletized at the Argerich Experimental Farm facilities of the Universidad Nacional del Sur, located 35 km S of Bahía Blanca.

2.2 Animals and experimental period

Angus heifers, 280 kg initial weight, were used. Heifers weights, without overnight fasting, were taken at approximately 21-d intervals. Total experimental period lasted 68 days.

2.3 Chemical analyses

Whole wheat straw and both supplements were analyzed for crude protein (CP) and *in vitro* dry matter disappearance (IVDMD). CP was determined by standard macroKjeldahl procedure and IVDMD was determined according to Tilley and Terry [38]. Both supplements were analyzed for Ca and P content. Weeping lovegrass pasture was analyzed for CP and neutral detergent fiber (NDF) according to Goering and Van Soest [14].
2.4 Estimation of rumen degradation parameters

To estimate rate and extent of disappearance of GSS from the rumen, the nylon bag technique described by Orskov and McDonald [27] was applied. Three rumen fistulated mature wethers were fed good quality alfalfa hay previous and during the trial. Nylon bags (10 by 15 cm; Ankom Technology, Fairport, NY, USA) containing 3 to 5 g, as feed basis, of GSS were introduced in the rumen through the canula. Bags were closed and attached to nylon string measuring c. 80 cm, weighted with small iron nuts. Incubation times were 0, 5, 1, 3, 6, 10, 24, 48, 72 and 96 h. After each removal from the rumen, bags and contents were washed and hand-squeezed under warm running tap water for 15 min until the wash-water was clear. Bags were dried in a ventilated oven at 60 °C for 48 hs and then weighted.

The percent disappearance of the dry matter at each individual incubation time was calculated as the difference between the feed and the portion remaining after incubation in the rumen. These values were used to determine the portion in the soluble a fraction, degradable b fraction and fractional rate of disappearance of the degradable b fraction using non-linear regression. The following equation was used:

\[ y = a + b \left[ 1 - e^{(-ct)} \right] \]  

(1)

where \( y \) is percentage of material in the bag which disappeared at time \( t \), fraction \( a \) is the \( y \)-intercept which is the amount of soluble material determined in the 0 h bags which has been subjected only to the washing procedure, fraction \( b \) is the amount which in time will degrade (degradable fraction) at a fractional rate \( c \) (% h\(^{-1}\)). A linear iterative curve fitting procedure was used to reduce residual sums of squares associated with the regression model thereby solving for the factors in the exponential equation (Eq. 1).

The experiment was analyzed as a completely randomized design. The general linear model procedure of SAS was used (SAS [32]).

3 Results and discussion

Composition of forages, ground soybean grain and supplements are given in Table 2.

Table 2. Chemical composition of feeds (dry-matter basis).

<table>
<thead>
<tr>
<th></th>
<th>CP</th>
<th>IVDMD</th>
<th>NDF</th>
<th>Ca</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground soybean seed</td>
<td>28.6</td>
<td>81.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>3.8</td>
<td>41.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GSU supplement</td>
<td>20.7</td>
<td>85.3</td>
<td>-</td>
<td>1.0</td>
<td>0.8</td>
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<tr>
<td>GS supplement</td>
<td>19.4</td>
<td>90.4</td>
<td>-</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>NS Weeping lovegrass pasture</td>
<td>4.0</td>
<td>-</td>
<td>70.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Ground soybean seed had a high IVDMD value. Estimated values of GSS degradability parameters were: \( a = 45.6 \pm 1.2; \ b = 50.7 \pm 1.7 \) and \( c = 0.06 \pm 0.006 \). Sum of the soluble (a) and potential (b) degradable fractions of GSS showed a higher degradability than the *in vitro* method.

Average daily gains of heifers along the experimental period are given in Table 3.

The deleterious effects of grain supplementation on forage utilization suggests that grain based supplements should be carefully formulated. Corn supplements formulated with inadequate ruminal available protein appear to depress hay digestibility and intake to the extent that the anticipated energetic advantages for grain supplementation are much less than expected when the total digestible nutrients contents of the grain is considered.

Stewart *et al* [36] concluded from *in vitro* studies on the effect of starch on fiber digestion that high amounts of starch have detrimental effects on the digestion of roughages, but that small amounts stimulate bacterial digestion of straw by enhancing the bacterial attachment to particulate matter.

Over a wide range of forages, depressions in forage digestion with added grain worsen as forage quality declines (Doyle [11]; Beever *et al* [4]), perhaps because microbes intimately associated with fibrous digests contribute more to digestion of low- than of high-quality forage (Akin [1]).

Bowman and Sanson [5] predicted that supplemental starch would not depress the intake of low-quality forage by beef cattle until feeding levels exceeded 0.5% body weight. The negative effects of starch on intake of low-quality forage have been ameliorated by the addition of supplemental protein in some cases (Del Curto *et al* [8], Sanson *et al* [31]) but not in others (Rittenhouse *et al* [30]; Hennessy *et al* [18]). In this experiment starch content in the supplements were below 0.5% bodyweight.

<table>
<thead>
<tr>
<th>Time after initial weight (d)</th>
<th>29</th>
<th>43</th>
<th>57</th>
<th>68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>GSU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td></td>
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</tr>
</tbody>
</table>

*Means within a column with different letter differ (P< 0.05).

Animals under NS treatment showed a gradual drop of ADG. This could be attributed to a decay in rumen conditions for an adequate microorganisms growth. A low bacterial population produce less volatile fatty acids and bacteria proteins in the rumen (Owens and Goetsch [28]).

Among animals that received supplement the highest ADG was obtained in the GS treatment. Although nonprotein N is the cheapest form of supplementary crude protein is not as effective as natural protein. That can be attributed to better
quality of natural protein (GS treatment) compared to urea plus natural protein, as a protein source for ruminal bacteria. It is concluded that whole soybean seed and urea improves ADG of heifers fed a low quality forage such as cereal straw. Higher energy content and concentration of preformed amino acids could account for better ADG in the GS diet compared to GSU diet.

In the marginal areas, sustainable agriculture implies that a major emphasis must be placed on reducing the vulnerability of farmers and herders to resource fragility and natural hazards (Jazairy et al [21]). The key to improving the sustainability of systems is to halt any further deterioration of the natural resource base, that is, agricultural land, and the associated loss of soil productivity. This can be achieved largely by implementing sound soil and water management practices.

Given the fragility of the vegetation cover and its importance for maintaining the soil resource, it is desirable to identify and establish a management system, which is conservationist as well as economically viable. Indeed, any system which does not employ conservationist methods is likely to be economically unviable, because of the rapid deterioration of the resource when improperly used.

Of primary importance is the desire to develop agricultural systems that sustain production in the long run without degrading the resource base. Productivity cannot be sustained if the resources that support productivity are degraded. The problem of the sustainability of different types of land use demands that attention be paid simultaneously to production potential and environmental consequences in searching for adequate technologies.

It is becoming obvious that keeping the balance between increasing productivity and preserving the native biological machinery has a cost either to the individual farmer or to the whole society, which needs to be considered when making comparisons with other unsustainable, exploitative production systems.

The ultimate goal of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment, and enhance health and safety, and to do so over the long-term. The means of achieving this is low-input methods and skilled management, which seek to optimize the management and use of internal production inputs in ways that provide acceptable levels of sustainable crop yields and livestock production and result in economically profitable returns. (Parr et al [29]).

The use of ground soybean seed, urea, corn grain and cereal straw available to farmers in the major areas of livestock production in Argentina will allow to get a good animal performance. That will alleviate the pressure in the use of native forage resources and keep the stability of the semiarid ecosystems under the overgrazing threat, especially in winter time.
Acknowledgments

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References


