Supplementation of Temperate Pastures

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SUPPLEMENTATION OF TEMPERATE PASTURES

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Abstract

Generally in temperate regions, beef and milk were produced on extensive systems with forage from perennial pasture and natural grassland being the main component of animal diet. Supplementation on pasture was usually applied strategically to supply nutrients to grazing cattle only when forage availability was not enough to satisfy animal's requirements. At present beef and dairy production systems have become more intensive and even when forage from pasture continue being the main component of the diet higher level of different type of supplement are fed to the animals. Intensive systems are characterized by a higher stocking rate capable of consuming the spring regrowth of pasture, and by an increment in the amount of supplement offered to the animal. Two factors affect nutrient intake when cattle on grazing are supplemented with concentrate: 1) substitution rate of pasture by concentrate, and 2) the depression on fiber digestion. On high quality pasture the effect of supplementation on substitution rate is more important than the effect on fiber digestion while in low quality pasture the opposite occur, it means the depression on fiber digestion is what more affect nutrient intake. In winter forage production is minimum and cattle is supplemented to maintain the stocking rate needed to graze efficiently pasture in spring. Corn silage is generally supplemented in winter and in this case animal performance will be affected by the energy contents of corn silage, which it will depend mainly on the grain content in the total plant and the digestibility of the rest of the plant. In autumn the grazing diet is usually unbalanced in term of energy and protein because an excess of degradable protein in temperate pasture normally occur causing high levels of ammonium nitrogen in rumen fluid. Starch contained in barley and wheat grain or in high moisture corn are more readily available at ruminal level that starch from dry corn or sorghum being therefore those grain a better energy supplement to cows on grazing in the fall. However in several trial trying to balance autumn pasture with readily available starch, even when some effect on ruminal level was observed, not always an effect on milk yield or body weight gain was obtained. Summer supplementation on beef production is generally done to increase body weight gain when quality of mature pasture decrease and to finish the animals with an optimum fat deposition before slaughtering. Due to the importance that meat quality and composition is getting in the international market, different type and amount of grain supplementation on grazing or finishing in feedlot will have to be considered in order to produce the type of meat that each specific market will demand. Beef from grazing steers had a lower content of cholesterol, a higher amount of n-3 linolenic acid and a lower n-6/n-3 linolenic ratio. Linolenic acid from pasture would be the source for this conjugated unsaturated fatty acid in beef. The importance of those fatty acids relay on their incidence in reducing the risk of arterial coronary diseases. Pasture-finished steers had lower predicted lean yields, smaller rib-eye areas, and darker colored meat than grain-finished steers. Although a yellowish fat was obtained in steers

finished on pasture, grain feeding did not change fat texture, nor tenderness, juiciness, flavor and overall acceptability by consumers. Even when drylot steers had a higher performance and better carcass characteristics, compared to grazing steers, those parameters were improved when grazing was supplemented with grain. In dairy, considering the high losses of dietary nitrogen occurring in temperate pasture it could be suggested that the amount of amino acids reaching duodenum and available for absorption could be not enough to satisfy nutrient requirements of high yielding cows. However, responses to protein supplementation on milk production and composition are quite variable and generally disappointed. On milk quality, there is currently limited opportunity for dairy farmer with grazing systems to manipulate the composition of the N components in milk by supplementing different type of concentrate. As conclusion it could be said that there is not a unique approach to supplement animals on grazing. Each situation would require its own analysis to produce at the lowest cost the product that the specific marker requires.

Introduction

For many years beef and milk, in temperate regions, were produced on extensive systems with forage from perennial pasture and natural grassland being the main component of animal diet. Supplementation on pasture was usually applied strategically to supply nutrients to grazing animal only when forage availability was not enough to satisfy animal's requirements. At present beef and dairy production systems have become more intensive and even when forage from pasture continue being the main component of the diet, higher level of different type of supplement are included to the ration (Rearte, 1998). The need to optimize forage utilization by grazing animals and the seasonal changes of forage quality occurring throughout the year have done that supplementation is considered strategically depending on the productive objectives. The different supplementation approaches applied to the intensive production systems on grazing will be discussed in this paper. For a better understanding of the performance of cattle on pasture supplementation some parameters of pasture characterization and fresh forage digestion will be presented.

Pasture characterization

Annual production of temperate pasture will depends on climate, soil fertility and ecological condition. In Argentina, annual productions of mixture pastures were estimated ranging from 8 to 20 ton DM/ha, very variable from year to year and throughout the year (Figure 1). Dry matter production has his peak in spring, accounting in average 45-50% of the annual yield, decrease later in summer when pasture became more mature, has a new regrowth in autumn and decrease to his lowest growth rate in winter (Santini et al, 1975).

The objective in intensive production systems on grazing is to maximize forage utilization on spring, maintaining a high animal performance throughout the year, therefore supplementation approach will be different at different seasons of the year. In winter, when forage production is minimum cattle is supplemented mainly to maintain the stocking rate needed to graze efficiently pasture in spring while in autumn and summer the main supplementation goal will be to optimize individual performance. Animal productivity on grazing is not always satisfactory and individual performance expressed as body weight gain or daily milk yield is generally lower than the obtained on intensive systems based on concentrate feeding. Pasture availability and forage quality are the main constraints affecting animal productivity. Even when high quality temperate pastures are an optimum and cheap source of nutrient for ruminants they not always supply the correct amount of nutrients that high performance cattle require. Nutritive value of pasture depends on dry matter intake, forage digestibility and efficiency of utilization of end-products of rumen digestion. On grazing systems forage intake could be affected by pasture availability, but when it does not occur forage digestibility may become the limiting factor. The quantity and quality of pasture on temperate regions are influenced by management, environment and by species and cultivars. Harvest timing at grazing is the most significant management factor due to the negative relationship between grass maturity and forage quality (Cherney et al, 1993).

In temperate regions, grasses are rarely grows in monocultures but are generally components of pasture mixtures with other grasses and legumes. Grass and legumes species and cultivars differ in chemical composition therefore their contribution to the pasture mixture will also affect forage quality. This generally occur because forage quality of legume is superior relative to grasses, differences attributable to the lower cell wall concentration and higher crude protein concentration of legumes compared with cool-season grasses (Buxton, 1996). Nutrient content of forage from temperate pasture are generally higher when grazed than when offered to the animals in conserved form as hay or silage (Glenn, 1994). Ruminal digestibility of dry matter and ruminal degradability of protein is also normally high in grazed forage relative to non-pastured forages.

Rumen digestion of fresh temperate pasture

Forage digestibility depends not only on its stage of maturity, it means fiber and lignin content, but also on the digestion process that occur in rumen. Fiber digestion in rumen will depend on the digestion rate, which will be affected by bacterial activity, and the retention time in that compartment. Because of that, rumen environment is fundamental in defining forage digestion. Crawfor et al (1983), reported an optimum rumen fluid pH of 6.6-6.8 for a maximum fiber digestion and bacterial yield in the rumen. It is important to maximize bacterial yield and activity because it will not only improve fiber digestion in rumen, but it will also increase amino acids (AA) supply to duodenum. When rumen pH descends from the optimum, fiber digestion could be affected. Cellulolytic activity is reduced at pH lower than 6.0 and fiber digestion is ceased at pH of 4.3-5.0 (Hoover et al. 1984). Efficiency of microbial protein synthesis (MPS) would also be reduced at low pH values (Strobel and Russell, 1986).
Studies carried out at INTA Balcarce, in Argentina proved that rumen environment in cattle grazing high quality forage is different to that reported from cattle fed indoors with diets based on processed feedstuffs like hay, silage and concentrate (Rearte and Santini, 1993) (Table 1). Similar results were obtained by other authors working also with cattle grazing high quality pasture (van Vuuren et al, 1986; Carruthers et al, 1996).

Only on pasture of lower quality like wheatgrass (Agropirum elongatum), tall fescue (Festuca arundinacea), or ryegrass (Lolium perenne) at mature stage, rumen pH was 6.3-6.4. On forages of higher quality like oats or perennial ryegrass in early vegetative stage, rumen pH was 5.9-6.0. Legumes like alfalfa, even when they are supposed to have a higher buffer capacity, have also caused low rumen pH when grassed at vegetative stage. In addition to a low rumen pH, a high concentration of volatile fatty acid (VFA) (90-120 mmol/l) with a low acetate:propionate ratio were measured in rumen fluid of cows grazing high quality pasture. This and other studies reported a lower pH in animals grazing high quality pasture than the optimum mentioned earlier even when there was no evidence that a depression in fiber digestion or a lower microbial efficiency occurred (Carruthers et al, 1996). The low ruminal pH in grazing cattle is not consistent with the fiber content of pasture diet but it could be associated to the high VFA ruminal concentration or the high buffer capacity of fresh pasture diet (Erdman, 1988). It could also be possible that on grazing, salivation rate is lower than expected due to the low content of physically effective fiber in high quality pasture (Allen, 1995). Not only dry matter production rate and forage digestibility vary during the year but also others nutrients contents differ seasonally (Anrique and Balochi, 1993) (Figure 2). In autumn, although temperate pastures are very digestible, the forage produced is high in protein and low in energy resulting an unbalanced ration for cattle on only forage diet. In spring soluble carbohydrate content increase and forage became a more balanced diet.

It can be concluded that in cattle grazing high quality pasture, energy and protein unbalance at ruminal level may occur, due to the high content of highly degradable protein in pasture forage which are not matched by a high content of soluble carbohydrate (Beever and Siddons, 1986). Studies with growing cattle consuming fresh forage carried out by Beever et al. (1986), have shown that seasonal changes in nitrogen (N) content of pasture, can lead to different efficiencies for microbial utilization of ruminally degraded protein. Much of the N consumed by cows grazing high quality temperate pasture does not reach the duodenum due to hydrolysis of consumed protein to ammonia (NH_3-N), absorption from the rumen, conversion to urea in liver and excretion through urine (Beever, 1993a, Beever et al. 1986; Van Vuuren et al, 1990). Several trials with grazing animals have shown an excess of ruminal ammonia nitrogen, to satisfy microbial requirement for protein synthesis (Elizalde et al, 1996; Holden et al, 1994). The losses of ammonia nitrogen will depend on the availability of energy and its utilization by rumen bacteria.

In a trial carried out at INTA Balcarce (Elizalde et al, 1994; Elizalde et al., 1996), bacterial synthesis efficiency of cows grazing winter oats (WO) (Avena sativa) at five different maturity stage, autumn (A), early winter (EW), winter (W), spring (S) and late spring (LS), was studied (Table 2). The effects of dates of harvest on nitrogen metabolism showed that microbial N, g/kg organic mater digested in rumen (OMDR), varied from 24.6 to 32.6, and N lost varied between 44 and 7% of total N intake for autumn and spring pasture, respectively. These differences were associated with differences in the total protein and soluble carbohydrate contents of the forage at different times of the year. While in autumn the crude protein content of grass is very high, the amount of soluble carbohydrate is low compared to the concentration that temperate grasses have in spring. It is clear that an unbalance energy:protein at ruminal level occurs in cattle grazing WO in autumn. This unbalance is reflected in a higher NH_3-N concentration in rumen, well above the minimum required for an optimum bacterial activity. The different ruminal digestion of temperate pasture in spring compared to autumn could explain the differences obtained in animal performance.

The protein:energy unbalance of temperate pasture is even wider with legumes compared to grass. Rearte et al (1989a), working with dairy cattle grazing alfalfa pasture with 25% crude protein, reported an average ammonium concentration in rumen fluid of 40 mg/dl, with even higher values at some time of the day soon after intake peak. The negative effect of the unbalanced diet could also affect animal performance due to the increment in the metabolic cost of synthesizing urea from ammonia in liver previous excretion through the urine (Greaney et al, 1996). With a normal load of ammonia, the hepatic removal is in balance with the hepatic output of urea-N, but when the amount the ammonia reaching the liver is too high it was observed that the output of urea-N could be substantially greater than the ammonia removal (Pippard et al, 1993). It would mean that an alternative source of essential $-NH_3$ radicals to support ammonia removal by the liver, provided for example by an increased catabolism of amino acids could be occurring. In that case if the extent of amino acids catabolism is significant, the net output of free amino acids, peptides and export proteins from the liver could be restricted, affecting consequently muscle deposition and body weight gain.
Even when the energy:protein unbalanced ratio was common on several trial with cattle on grazing, a low efficiency of microbial protein synthesis was not detected (Elizalde et al, 1996; Beever and Sidoons, 1986). The high ammonium concentration in rumen would be

consequence of excess of protein in the diet more than a lower efficiency of microbial protein synthesis.

Concentrate supplementation

Animal response to concentrate supplementation on grazing systems will depend on availability and nutritive value of pasture, and on level and nutritional composition of supplemented concentrate. Two important factors affecting nutrient intake should be considered when cattle on grazing are supplemented with concentrate: 1) substitution rate, it means the decrease in pasture dry matter intake per unit of concentrate intake, and 2) the depression on fiber digestion that energy supplement may cause. Although both factors are close related, a clear tendency of the effect between them doesn't exist. The depression on fiber digestion caused by the energy supplementation is higher in low quality forages than in those of high quality (Galyean and Goetsch, 1993). However the depression in the forage consumption is smaller in the forages of lower quality (Elilzalde et al, 1999a; Paterson et al, 1994). Intake of metabolisable energy (ME) when forage and grains are fed together may be lower or higher than expected from feeding these components separately. These interactions, or associative effects, are due primarily to changes in the intake and/or the digestibility of the fibrous components of forage. Effects on voluntary forage intake (substitution effects) are usually much larger than on the digestibility of fibrous components, although the change in forge intake may be a consequence of change in the rate of digestion of the fibrous components (Dixon and Stockdale, 1999).

Supplementation effects on pasture forage substitution - When grain is supplemented to grazing animals, pasture intake decreases due to the substitution effect of the forage by the grain, however total dry matter intake and energy intake are usually higher. The substitution rates reported for grazing ruminants are variable, and depend on the quality of the consumed forage. Minson (1990), reviewing 19 trials with different categories of animals, reported an average substitution rate of 0.69. However, the substitution rate was lower when grain was supplemented to low-quality forages (Sanson and Clanton, 1989). Mayne and Weight (1988) working also with pasture ad-libitum cited substitution rates ranging from 0.21 to 0.50 kg forage organic matter intake (OMI) reduction per kg of concentrate OM offered, and explained the results by a reduction in grazing time. Marsh et al. (1971) recorded a reduction in grazing time of 22 minutes per day per each extra kg of supplemented concentrate.

The desired level of substitution of supplements for forage thereby depends on amounts of available forage, but it also depends on the limits of feed intake and the constraints of ration formulation in meeting nutrients requirements (Horn and MacCollum, 1987). In ruminants consuming large amounts of high digestible forage, EM intake is high and the voluntary intake is likely to be limited by metabolic mechanism. If grain is included in the diet the animal largely replace ME form forage with ME from grain (Dixon and Stockdale, 1999). When medium to low digestible forage is consumed, ME intake usually is lower than the capacity the animal has to utilize nutrients, and rumen fill mechanisms can be expected to constrain intake (Forbes 1995; Pittroff and Kothmann, 1999). Although substitution rate is low in low quality forages, it is often of sufficient magnitude to cause substantial inefficiencies in the utilization of grain (Dixon et al., 1993; Rafia et al., 1995). The magnitude of the substitution when intake is limited by rumen fill, will depends on the extent to which grain, either directly or indirectly, change rumen fill and the animal tolerance to rumen fill (Dixon and Stockdale, 1999). Because of their high ME density the direct contribution of grains to rumen fill will be lower, compared to forage. However, grains may have indirect effects on rumen fill. They could modify the amount of undigested residues accommodated in the reticulo-rumen, by changing the rate of microbial digestion of fibrous components, or possibly by influencing the removal rate of undigested residues from the rumen.

Because substitution rate, besides being affected by the dry matter (DM) forage digestibility, could be influenced by the energy demand of the animals (Jarrigue et al, 1986), it is not possible to simplify in a singular substitution curve. Variations in animal physiological stage, cattle activity (stall fed vs grazing), and forage quantity and quality may produce different substitution rates for a given concentrate fed at given level. Hence, experiments should be conducted under similar conditions to the production environment in which the results will be applied (Horn and MacCollum, 1987). However in many instances, maximum intake of forages surpasses the animal´s requirements and its metabolic ability to utilize nutrients. In these situation substitution of high quality pasture by supplemented concentrate could probably result in a more efficient use of nutrients than "full –feed grazing.
Tayler and Wilkinson (1972) worked with steers grazing high-quality ryegrass in a two period trial (75% and 66% digestibility in period 1 and 2 respectively), supplemented with concentrated (85% rolled barley and 15% protein supplement) at levels between 0 and 100% total diets. Although concentrate supplementation caused a high rate of substitution of high quality pasture by grain (0.97 and 0.95 in period 1 and 2 respectively), the empty body-weight gain (EWG) was increased lineally by the proportion of concentrate in the diet (Figure 3).

In period 1, the lineal equation estimated an increment of 7.3g in the EWG for each percentage unit increment of concentrated in the diet while in the period 2 this increment was of 12.3 g. The improvement in the EWG caused by the suplementación was larger when fed the ryegrass of lower digestibility (period 2), but the EWG of the unsupplemented steers was higher on high quality pasture (.714 vs .270 kg/EWG/d). Because a high rates of substitution occurred on high quality forage, the improvements in the EWG would be attributed to an increment in the intake of net energy and to an improvement in the efficiency of use the nutrients. The substitution rate on pasture has also been related to energy:protein ratio of the grazed forage. Moore et al. (1999) determined a high reduction in forage intake when the TDN:CP ratio in forage were <7. This ratio is indicative of high quality forage and not N deficit in relation to available energy. Low quality forage (TDN:CP>7) intake was also reduced when TDN supplemented intake were >.7% BW or when forage intake alone was >1.75% of BW. However, forage intake was increased when TDN:CP was>7 and cattle received N supplementation. When low-quality forage intake was incremented by N supplemental, NPN and protein meals were apparently equivalent as protein sources.

Meijs, (1986) working with dairy cows grazing high quality pasture with high allowance, determined a different substitution rate depending on concentrate composition. The mean substitution rate was reduced from 0.45 with the high-starch concentrate to 0.21 with the high-fiber concentrates. However when forage allowance and forage intake were low, starchy concentrate had little effects on substitution rate (Meijs and Hoekstra, 1984). The effects of concentrate type may not be as marked at the lower concentrate levels that are common for grazing dairy cows (Meijs, 1986). The low substitution rate when high-fibrous concentrate were supplemented to grazing dairy cows, can by attributed to a less perturbation of ruminal environment. High levels of easily fermentable substances, such as soluble sugars or starch, tend to decrease ruminal pH and increase concentration of VFA and lactate in the rumen fluid. This effects, besides being affected by concentrate type, is varying by herbage composition (Galyean and Goestch, 1993; Dixon and Stockdale, 1999). Several by-products (e.g. soybean hulls, citrus pulps, wheat middlingd, and brewers grain) contain less starch and more cell wall carbohydrates than the cereal-based concentrate. Their grater filling effects in the rumen could be counterbalanced by a favorable influence on rumen fermentation (Jarrigue et al., 1986) but the final results will depends on the digestibility of the by-product cell wall.

Considering the production systems, the reduction in forage intake occurring when concentrate is supplemented, could be both desirable (and necessary) or undesirable (Horn and MacCollum, 1987). If the objective is to stretch existing forage supplies (ex. high stocking rate in winter), then a decreased in forage intake is desirable. In contrast if forage supplies is not limited (low stocking rate), then decreasing forage intake will generated an inefficient use of the supplements (Elizalde, 2000).

Supplementation effects on fiber digestion - Since grains are usually more digestible than forages, a linear increase in digestibility of the diets might be expected as the proportion of grain in the diet is increased. However, digestibility in the entire gastrointestinal tract (GIT) of mixed grain-forage diets often increased less than should occur with forage and grain when they are fed separately, due to the reduced digestion of the fibrous components of the forage. (van der Linden et al., 1984; Kennedy and Bunting 1992; Gribsy et al., 1993). Ruminants can partially compensate a reduced rate of fiber digestion in the rumen by increasing retention time of fibrous residues in this compartment, but when this occur forage intake usually decrease (Dixon and Stockdale, 1999). The pH of the rumen fluid is reduced by digestion of grain and this appears to be an aspect of growth of cellulolytic bacteria difficult to manipulate (Russell and Wilson, 1996). The rate of digestion of NDF is near the maximum at rumen fluid pH of 6.2-7.0, and drop precipitously in a nearly linear fashion to zero digestion rate at pH 5.5- 5.7 (Pitt et al., 1996; NRC, 1996). The NDF digestibility reduction caused by addition of starch to the diet could be attributed to a lower ruminal pH or directly to presence of starch in rumen. The abundance of cellulolytics organisms relative to fiber substrate that is susceptible to colonization ensures some level of fiber digestion even at low pH. However, if there are not periods during the day in which ruminal pH approaches or exceeds pH 6, and growth of the cellulolytics can proceed, the population of cellulolytic organisms will diminish. In that case, growth cannot keep pace with the dilution rate, and wash-out of the organisms will occur (Satter et al., 1999). Energy supplements may have different effects on rumial pH depending on the feedstuff composition of the supplement, the form and type of forage, the resulting rate of particle fragmentation as well as the buffering capacity of rumen fluid per se (Horn and MacCollum, 1987). The effects of readily fermentable carbohydrate (RFC) to reduce rumen DM digestibility of forages has been linearly related to their content of neutral detergent fiber (Dixon and Parra, 1984; Dixon, 1986).

The increments in fiber digestion depression by dietary RFC, with advance of maturity, decline of quality and increases of fiber contents could be attributed to three principal theories. First: Fiber-digesting microbes contributes more to digestion of low than of high-quality forage (Akin, 1989; Galyean and Goesch, 1993). Second: When quality of forage decrease, the concentration of the main substrates for the microbial growth usually decreases. When formulating energy supplements, one must insure that ammonia requirements of ruminal microorganisms are met. Unfortunately, two questions remain: What is ammonia requirements of ruminal microorganism? and, to what extent is ruminal ammonia concentration indicative of an overall balance between available energy and protein?. Third: The ruminal environment generated by high-quality pasture digestion is similar to the digestion occurring with high-grain diet (Rearte and Santini, 1993). The extent and rate of degradation of OM could be higher in fresh high-quality forage than in the cereal grains commonly used as supplements (ground barley, corn and sorghum grains). The alteration caused in the rumen environment by added grain is more evident in low-quality forage than in high-quality one.

Elizalde et al (1999a), supplementing steers fed high-quality fresh alfalfa, with three levels of cracked corn, reported not effect of supplement on ruminal OM and total dietary fiber (TDF) digestibility. Ruminal pH decreased linearly as levels of corn in the diet increase, without affecting ruminal fiber digestion. The high quality fresh alfalfa (20.4 % CP, 41.6% NDF) used in this trial could explain the lack of effect of grain on fiber digestion. Moreover, the supplementation with grain generally affects less the fiber digestion of legumes that grasses (Galyean and Goescht, 1993). Similar results obtained García et al (2000) working with heifer fed fresh oats alone or partially replaced 1:1 (DM basis) by ground corn or rolled barley grain. In this study ruminal and total tract digestibility of OM and NDF were neither reduced by supplementation of barley or corn (30% of total DM diet). Organic matter intake was neither affected by partial replacement of fresh oats by ground barley or corn, what is consistent with the lack of effect of supplements on fiber digestion. Percentage of the total digested OM that were digested in rumen tended to be lower in supplemented animals compared to the ones fed on fresh oats alone. Rumen fluid pH was not affected by grain supplementation due perhaps to the similarity in the amount of OM degraded in all treatments. In Elizalde et al. (1999a) trial, OM intake was increased linearly as supplementation level augmented. Even when OM degradability was no affected, the total amount of OM degraded in rumen increased at higher supplementation levels, what it would explain the lowering in ruminal pH. Even when Elizalde et al.(1999a) used a legume and García et al. (2000) a grass as basal diet, the high quality of the forage, reflected in their low NDF content and high digestibility, determined that the supplement did not affect the digestion of the forage fiber. At same conclusion arrived Pieroni (2000) feeding cereals grains of different rumen degradability to steers grazing high-quality pasture. Here again, concentrate supplementation at 35% of total diet, did not affect ruminal pH, neither NDF in situ disappearance.

The lower interference of grain supplemented in fiber digestion when high digestibility of fiber forage is fed has been reported by others (Van Vuuren et al., 1993; Vanzant et al., 1990; Bowman and Sanson, 1996). However, Berzaghi et al (1996) reported different results when grain was supplemented on a lower quality forage (62.6%NDF). In this study, total tract digestibility of OM and NDF was decreased by supplementation with cracked corn at moderate levels (35% of DM diets). It agree with Galyean and Goescht (1993), who suggested that grain supplementation altered microbial population more on low than on high-quality forage. In forage of low quality, the digestion process is slower due to the complexity of fiber structure what it make necessary a sequence of events to occur in which different bacteria species will interact (Galyean and Goetsch, 1993). Beside that, energy supplementation on low quality forage may be detrimental because it will increase the nitrogen deficiency at ruminal level. However, still with a reduction in OM and NDF digestibility caused by the supplemented starch, the supply of energy is higher in the supplemented cows, enhancing the animal performance (Dixon and Stockadale, 1999).

The effect of concentrate supplementation on fiber digestion will depends also on the type of concentrate used. Van Vuuren et al (1993) compared the effects of high-starch or high-fiber concentrate supplemented to dairy cows grazing high quality pasture. In this study, ruminal OM and NDF digestibility was decreased when high-starch concentrate (23.3%NDF, 46.1% starch) was fed compared to unsupplemented pasture or to a high-fiber concentrate supplementation (40.7%NDF, 4.7% starch). Total tract OM and NDF digestibility was also lower in high starch supplemented cattle. Ruminal pH was not different among treatments suggesting that the addition of readily fermentable carbohydrates would be the main cause of the depression in cell-wall digestion. The reduction occurring on OM and NDF total tract digestibility when high quality fresh forage (ryegrass with 18.1% CP, 41.3% NDF) was supplemented by a high-starch concentrates does not agree with others (García et al., 2000; Elizalde et al., 1999a). However, it has to be noticed that in this trial a higher level of concentrate was applied (43%).

The previously reviewed results, allow to suggest that the DM degradability of high quality fresh forages would not be modified by supplementing concentrated at levels no higher than 35% of total diet, and unless the offer of feeds is restricted, feeding high digestible supplements, will increase the total OM intake. As a consequence, total amount of OM degraded in rumen will be higher and the ruminal pH could be lowered. However, because NDF digestion would not be altered, concentrate supplementation would offer the possibility to increment nutrient supply without reducing forage utilization.

1 - Energy supplementation

Supplementation for balancing pastures - Cereal grains such as corn, oat, sorghum barley and wheat and agroindustrial byproducts such as wheat bran or whole cottonseed are the main source of energy to supplement grazing cattle in temperate regions. Concentrate supplementation to cattle on pasture was generally considered a way to increase the dietary nutrient supply by the addition of the nutrient contained in the concentrate, it means that an additive effect was expected. Even when that statement is still valid, concentrate supplementation could also be seen as a pasture balancing tool, adding those nutrient in which pastures are deficient, improving the rumen digestion metabolism and consequently the nutritive value of the pasture (Beever, 1993b). The effects of concentrate supplementation to grazing cows on rumen digestion will depend on type and level of concentrate used. Energy supplementation with cereals grain to synchronize the rate of nitrogen supply by degradation of forage protein could improve utilization of rapidly degradable protein, improves microbial protein synthesis, decreases N losses in the urine and the cost of this excretion and consequently enhance animal performance (Van Vuuren et al, 1993).

Several trials were run trying to improve nutritive value of temperate pasture by supplementing grazing animals with different type and levels of concentrate. Elizalde et al (1999b), working with steers on fresh alfalfa diets and supplemented with different levels of cracked corn (0, .4, .8 y 1.2 % of BW), reported a linear reduction in ruminal N losses and crude protein degradability as supplementation level increased. Even when efficiency of net microbial CP synthesis was not affected by treatment, the duodenal flow and the small intestinal disappearance and digestibility of total N and total, essential, and nonessential AA was increased at higher supplementation levels. At similar conclusion arrived Carruthers et al (1996), supplementing non structural carbohydrate (NSC) to dairy cows grazing a ryegrass and white clover pasture. These results proved that energy supplementation could be an excellent tool to improve the utilization of nitrogen in high quality pasture and to increase the amount of amino acids flowing to and disappearing from the small intestine.

But not only the amount of energy supplemented but the type of carbohydrate and the supplementing method used may affect nutrient utilization and animal performance. Starch degradability could also be important when trying to balance high protein pasture. Starch from wheat or barley grains is more degradable at ruminal level than starch from corn or sorghum therefore, these grains could be a better source of energy for cattle grazing high protein pastures in autumn (Kloster et al, 1996). In spring, on cattle with no energy deficiency in rumen, corn would be the best grain because it will supply energy directly at intestinal level where starch is digested (Galloway et al, 1993). García et al, (2000) studied the effect on forage digestion and bacterial protein synthesis of supplementing ground corn (low rumen degradability) or barley grain (high rumen degradability) to Holstein heifer grazing winter oats of high N content. The control group had winter oats forage as the only component of the diet and the results are presented in Table 3.

In this study total OM intake was similar among treatments, and also flow and apparent digestibility of OM in the total track (TT) were similar among diets. Analyzing the N fractions, N intake was 29% greater for the only oats diet than for the supplemented diets and tended to be greater for corn than for barley diet. However, duodenal flows of total N and non ammonia N (NAN) were similar for the three diets, resulting in a greater efficiency of N utilization relative to N intake when grain was included in the diet. Expressing the duodenal NAN flows as a proportion of the digestible OM intake (g/kg) no differences were observed among treatments. Intake N recovered at the duodenum increased from 60.2 to 66.6% or 69.6% when oats pasture were supplemented by corn or barley. Ammonia concentration in rumen was greater for only oats diet than for supplemented diets and for corn than for barley diet. These differences could be expected because barley starch is more rapidly fermented in the rumen than corn starch. This would result in a greater uptake of ammonia N by rumen bacteria and in a faster depletion of ammonia N. However, the similar amounts of starch digested in the rumen for barley and corn diets, together with the similar efficiencies of bacterial protein synthesis observed in all diets, suggest that the differences in ammonia N concentration were due to differences in total N intake rather than to differences in N uptake by the microorganisms. These results are in agreement with those reported by Beever et al (1985) and van Vuuren et al. (1993) when working with fresh perennial ryegrass and by Elizalde et al (1999b) working with alfalfa. It seems that energy provision by the fermentation of high quality fresh forage DM would be sufficient to maximize rumen microorganisms activity. Therefore, the response to supplementary grain in terms of animal production may be negligible unless a higher intake of total nutrients by the supplemented animal is achieved. Several others trials were run trying to match energy:protein degradation in rumen by supplementing readily available carbohydrate to dairy cows grazing high quality pasture (Table 4).

Milk yield and composition, rumen environment and grain digestion was compared in grazing cows supplemented with steam flaked corn (SFC) of dry grounded corn (DGC) by Bargo et al (1998) in diets composed by 25% grain, 15% corn silage and 70% pasture. In this trial milk yield and composition was not affected by processing methods of supplemented corn. Neither rumen fluid pH nor total VFA concentration was affected by treatment but SFC supplementation reduced NH_3 in rumen. SFC presented a significantly higher soluble fraction, degradation rate and effective degradability of DM than DGC, what could explain the lower concentration of NH_3 in rumen due perhaps to a better utilization by the rumen bacteria. Similar results were reported by Delahoy et al (1998), working also with cows on grazing and supplementing concentrate containing 66% cracked corn (CC) or SFC at 1 kg of DM per 4 kg of milk produced. In this case, SFC supplementation didn´t affect milk yield and composition either but decreased urea N concentration in blood and milk. In another trial comparing the same processing methods but in sorghum grain Pieroni et al (1999), arrived to similar conclusion. In this study 7 kg of concentrate (5 kg sorghum grain, 2kg sunflower meal) was supplemented to cows grazing high quality pasture (17% CP, 45.6% NDF, 65.6% IVDMD). Here again, steam flaked treatment increased degradation rate in rumen and reduced ruminal ammonium concentration but had not effect on milk yield and composition. With the same objective of improving N utilization in cows grazing temperate pasture, Alvarez et al (1995), tested high moisture corn (HMC) as a supplement of high degradability compared to dry grounded corn (DGC). High moisture corn grains had a higher soluble fraction and a higher ruminal rate of degradation of DM and starch than dry corn what have made NH_3 rumen fluid concentration to decrease. Except for a tendency to produce milk with a higher protein content, those differences were not reflected in milk production and composition. No differences in milk yield and composition was reported either by van Vuuren et al (1986) when supplemented grazing cows with 7 kg of high (25.8% starch) or low (1.5% starch) starch concentrate. Even when supplemented cows had a lower ammonia concentration in rumen, milk yield was similar to the no supplemented cows.

In all of the presented studies a better utilization of dietary N, reflected in lower ammonium concentration in rumen or urea in plasma and milk, was reported when the more readily available starch was supplemented but an improvement in milk yield was not achieved. It is important to notice that in these studies high quality pasture were the main component of the diet and concentrate comprise no more than 30% of total diet. Identical results were reported by Reis et al (1996), with dairy cows grazing an alfalfa-brome-orchardgrass mixed pasture and fed 10 kg of dry groud corn or steam rolled corn and by Castillo et al (1998) supplementing 7 kg high or low degradable starch concentrate (wheat-barley basis and corn-sorghum basis respectively) to cows grazing alfalfa.

Not only degradability of the supplement would be an important tool to synchronize ruminal degradation of supplemental carbohydrate with pasture nitrogen. Supplementation timing or patters could also improve nitrogen utilization by grazing animals. Kolver et al (1998), compared milk yield and composition and some nitrogen status parameter in cows receiving corn supplementation at two different time. One group of cows received the supplement at the time that pasture was fed (synchronous) and the other group received the same amount of grain but 4 h after pasture was fed (asynchronous). In this study a orchardgrass, Kentucky bluegrass and white clover pasture was used (22%, 55.2%, and 60.7% CP, NDF, and IVDMD respectively) and 10 kg of ground corn were supplemented. Even when daily average ammonia concentration in rumen was similar en both treatments, cows with synchronous diet had a peak ammonia concentration at 3 and 5 h after pasture feeding in the morning, 33% lower than cows with de asynchronous diet. Blood urea N followed a similar patter than rumen ammonia. Ration of N effectively degraded in the rumen (RDN) to OM effectively degraded in the rumen (RDOM) was higher during the first 4 h after pasture was fed, for the asynchronous diet, but there were not differences in the quantity of OM, and N ruminally degraded or in the ratios of RDN to RDOM. Based on ruminal concentration of ammonia, synchronous ruminal release of supplemental carbohydrate with pasture N, seems to improve ruminal N utilization, however these changes were not large enough to change the N status, neither the performance of the grazing dairy cows.

Supplementation for increasing stocking rate - Supplementation can reduce the variation in forage intake when pasture availability is inadequate and can allow a higher stocking rate and an increased efficiency of land use (Phillips, 1988). Increased stocking rate in temperate grassland would improve utilization and output of utilizable metabolic energy. However, herbage availability may be reduced and cattle performance may decline consequently. If animal production is reduced, the proportion of the feed used for cattle maintenance will be increased and efficiency will decline. In addition, fixed cost per hectare would increase, therefore the balance among these factors will be what will determine the optimum stocking rate to be applied (Phillips, 1988). When maintaining a high stocking rate in winter is the main objective of the feeding program, conserved forage become an ideal supplement for grazing cattle due to its higher substitution rate compared to concentrate supplementation. Substitution rate of pasture forage by silage is generally equal to or less than 1.0, being higher as supplementation level increases (Bryan and Donelly, 1974). Animal performance of grazing cattle supplemented with silage will depend on forage availability and quality and on the amount of CS fed and its quality. When herbage intake is restricted and silage is offered ad libitum silage intake will depend on the level of pasture restriction. If silage is of lower or similar quality to herbage, inclusion of silage in the diet generally results in a depression in cattle performance relative to non-restrictive forage diet. When herbage allowance is not restricted offering silage as a supplements will decreased herbage DM intake, but increased total DM intake. In this situation animal performance could be improved (Phillips, 1988).

Corn silage supplementation on grazing systems could not only act diminishing herbage intake variation but also offering potential benefits of a more balanced diet if the grain content of silage is high (Phipps, 1978). The inclusion of corn silage high in grain to a high quality pasture diet will increased the amount of non structural carbohydrate in relation to the rumen degradable protein. When crude protein content of pasture diet is higher than 14%, corn silage supplementation may reduce NH_3 concentration in rumen fluid improving nitrogen utilization by rumen bacteria. In that situation milk protein content could also be augmented (Moran et al., 1986). On the other side, considering the low protein content of corn silage and avoiding reducing DM intake, it is recommended not to overcome 40-50% of diets with this feed at less a protein supplement is incorporated (Leaver, 1985; Phillips and Leaver, 1985). Milk yield was increased by offering corn silage on restricted pasture but was decreased when high quality forage was offered ad libitum and corn silage was included at a high level in the diet or offered at a restricted levels overnight (Davison et al., 1982; Bryant and Donelly, 1974). When a positive response in milk production was obtained it was associated with increase in total DM intake (Elizalde et al., 1993).

However corn silage supplementation at low levels generally does not affect animal performance. Holden et al (1995), didn´t get any improvement in milk yield or total DMI when corn silage was supplemented at 10% of the total diet to milking cows grazing high quality pasture ad libitum. In this study substitution of pasture for corn silage reduced the amount of rumen degradable protein (RDP) in the total ration, and the blood urea nitrogen (BUN) concentration. Lack of milk response in the current study agrees with results of other studies (Davison et al., 1982; Huber et al, 1964). The quality of the pasture will define the response to the supplementation with corn silage. Due to the slow digestion rate of NDF of the corn silage (Allen and Oba, 1996), a high quality pasture of low NDF content and high digestibility would be recommended to get an improvement in total DMI. On the other side, corn silage supplementation to pasture with high NDF content of slow degradation rate, will diminish the rate of passage causing a reduction in the total DM intake (Elizalde, 1993).
Working with beef cattle, the average daily gain of steers grazing high quality pasture was not affected by supplementing corn silage at levels no higher than 35% of total diet, but important increment in stocking rate were obtained in supplemented cattle (Pieroni et al, 1998; Abdeladhi et al, 2000).

Based on the results reported by several authors, the main response of forage supplementation to grazing cattle should be looked mainly in the possibilities of increasing stocking rate more than in the improvement of individual animal performance. Maintaining a high stocking rate in winter, when pasture production is minimal, will allow to increase forage utilization later, during the pasture regrowth occurring in spring and summer. In this way forage supplementation on winter should not be analyzed considering only supplements cost and cattle performance, but by the global benefit achieved in the whole production systems throughout the year.

2 - Protein supplementation

Metabolizable energy intake seems to be the limiting factor affecting animal performance when dairy cows graze temperate pasture, however protein supply to the duodenum could also be limiting milk production of cows yielding more than 25 kg/day (Beeber and Siddons, 1986). Considering the high losses of dietary nitrogen occurring in temperate pasture it could be suggested that the amount of amino acids reaching duodenum and available for absorption could be not enough to satisfy nutrient requirements of high yielding cows.

Even when temperate pasture grazed at vegetative stage, usually contain enough protein to cover cattle requirement, there are circumstances where protein supplementation could be necessary. Agroindustrial by-products as sunflower meal, soybean meal, whole cottonseed, brewer's grain, fishmeal, meat and blood meal, etc. were the main source of protein available: Due to the BSE (bovine spongiform encephalopaty) problem occurred in Europe, perhaps only protein of vegetal origin would be allowed to be used in the future. In cattle with high protein requirement grazing temperate pasture, considering the high degradability of forage protein, protein supplement could have effect on animal performance only when a source of protein of low degradability would be included in the diet (Spears et al, 1980). Supplementation with protein of high degradability will enhance animal performance only when supplemented to cattle grazing pasture with low protein as is the case of subtropical pasture or too mature temperate pasture. In that case total dry matter intake would be increased due to an increment in the digestion rate and the rate of passage at ruminal level (Van Soest, 1982).

Several trials were run in last years, supplementing grazing cows with slowly degradable protein sources to improve amino acid availability at duodenum. However, responses on milk production and composition in cows grazing high quality forage are quite variable and generally disappointed. Santos et al, (1998) reviewing several studies where protein of low degradability were supplemented to dairy cows, concluded that increased rumen undegradable protein in dairy cow diets does not consistently improve lactation performance. Sometime, supplementing low degradable protein resulted in an inadequate supply of effective rumen degradable protein to the rumen microbes and in a change in the profile of amino acids absorbed. Others authors suggested that increasing undegradable protein in the diet, reduced microbial protein flow from the rumen, which was presumable due to the lack of supply of amino acids and peptides to the rumen microbes (Hoover and Stokes, 1991). It is important to notice that most of the studies reviewed by Santos were indoor trials, with cattle diet based on concentrate and conserved forage and supplementing high yielding cows of high protein requirement, animals in which supposedly, the highest response would be expected.

On grazing systems, milk yield of cows is generally lower than in indoor systems and dietary energy instead of protein or amino acids seems to be the limiting nutrient affecting animal performance. Therefore, milk production responses to low degradable protein supplementation in cows on grazing are not clear at all. Several protein source of low degradability were tested with cows on grazing and in most of the cases responses in milk production were minimum or null (Table 5). No response on milk production were reported when meat meal (Rearte et al, 1989b), feather meal (Bargo and Rearte, 1997), or roasted soybean (Piñeiro et al, 2000, Dhiman et al, 1997) were used as sources of low degradable protein in cows grazing high quality pasture and receiving concentrates at a level no higher than 30% of total diet. Fishmeal, reported by Santos et al (1998) as the protein source of highest response, was one of the supplements that occasionally increased milk yield of cows grazing high quality pasture, but that response was not consistent in all trials. While Schroeder et al (1998) reported a significant increment of milk in dairy cows grazing temperate pasture and receiving fishmeal instead of sunflower meal in the concentrate, Castillo et al (1999, 2000) in two consecutive years, reported not effect at all with the inclusion of increased level of fishmeal in the concentrate fed to dairy cows grazing alfalfa. Blood meal was also a protein supplement that increased milk production when supplemented to cows grazing high quality pasture (Schor, A., 1996). In this case a significant increment in pasture intake was reported, therefore the higher milk yield would be due a higher total intake more than to an increment in the amino acid supply to duodenum by the low degradable protein supplement.

Although animal performance was generally not improved by supplementing low degradable protein to average cows on grazing, a difference response could be expected if working with high yielding cows of higher protein requirement. However, Hongerholt and Muller (1998), neither reported any effect on milk production when working with grazing cows producing 39 kg/d. In this trial cows were supplemented with 9kg of concentrate with low or high degradable protein. An animal protein blend (contained meat and bone meal, blood meal, feather meal, poultry by-product meal and fish meal) and soybean meal were used as low and high degradable protein source respectively.

It is interesting to remark the lack of production response to the supplementation of roasted soybeans in grazing cows, even when the same supplement results in significant increases in milk production when supplemented to dairy cows fed alfalfa silage as the sole forage source in the diet (Dhiman et al, 1993). While at least 50% or more of the protein in alfalfa silage is as non-protein nitrogen, on grazed pasture more than 80% of the nitrogen is in true protein form. Even though this protein can be degraded in rumen, it is possible that a rapid turnover of liquid digesta in the rumen under grazing conditions results in some escape of grass protein before it can be degraded. This suggests that pasture on grazing are a more effective source of protein than conserved forage, therefore milk production response to low degradable protein supplementation in cows grazing high quality pasture not necesarely should be expected.

Effects of supplementation on meat or milk quality

Supplementation for finishing steers - In most countries, beef cattle is generally finished in dry-lot on high concentrate diets but in temperate regions it can be done directly on grazing, what it could make meat quality and composition different. On fresh forages chemical components presents in lipid fraction could pass to carcass meat and fat affecting their savor and color. Components derivative from pro-vitamins (carotene) are not degraded in rumen and could be found in carcass fat because their liposolubility, giving the meat the yellowish tone (Zhou et al, 1993). If forages are of good quality and allow rapid growth prior to slaughter and attempts are made to avoid cold-induced toughness, forage-fed beef should be of equivalent quality to grain-fed beef. But, what means beef quality? .

It is assumed that quality is what the market and the consumer demands. It is well known that even in countries with intensive production systems, consumers continue to demand leaner beef highly palatable. Generally, external fat and seam fat must be almost completely removed; however, a small to modest amount of marbling is still most desired.
Producers continue seeking alternative systems for producing beef with marbling but with a minimum of external and seam fat, and including the use of forage on the cattle diets is one alternative. Those grazing systems may range from finishing cattle off pasture, finishing on grass with limited amounts of concentrates, or growing cattle on pasture and then finishing them in dry lot for a relatively short period of time. Several trials were run to evaluate those systems.

McCaughey and Clipplef (1996), evaluated carcass and organoleptic characteristics of meat from steers finished on alfalfa/grass pastures or on grain in dry-lot. In this trial 60% of steers slaughtered directly off pasture met A-grade (Canadian standards) with the remainder grading B1 due to insufficient marbling. However a 33 days period of grain feeding was sufficient for all steers to meet A-grade standards. Pasture-finished steers had lower predicted lean yields, smaller rib-eye areas, and darker colored meat than grain-finished steers. Even when a yellowish fat was obtained in steers finished on pasture, grain feeding did not change fat texture, nor tenderness, juiciness, flavor and overall acceptability by consumers (Table 6).

At similar conclusion arrived others authors comparing finishing cattle on pasture or on dry lot of different length (Bidner et al,1986; Buchanan-Smith et al, 1991; Crouse et al, 1984; Schaake, et al 1993; Schroeder et al, 1980). It is important to notice that in those trial high quality pasture was the forage supplied. However, several authors continue assuming that feeding beef cattle on forages or grass alone produces a “lower quality beef” compared to animals fed on high amounts of grain (Bowling et al, 1977). There were two explanations for this observation. It is recognized that rapid growth prior to slaughter results in less background connective tissue and more tender meat than meat from animals slaughtered after a period of slow growth. The increased tenderness in meat from rapidly grown animals may in part be derived from a small overall decrease in the percentage of total collagen, but it seems more likely that the large quantity of recently synthesized and poorly cross-linked collagen dilutes out the older and tougher fibers. The lack of agreement, about the effect of forage or grain finishing diet on tenderness or palatability of meat, seems to indicate that there would be little differences in those quality parameters of meat, if both diets are compared in youthful animals slaughtered at a similar degree of finish.

Even when carcass and meat composition are important to define processing beef quality, dressing percentage is also relevant for the beef industry because it will indicate the final animal weight that would be available for processing. At similar energy intake, a bulky diet will increase ruminal content, the digestive tract will be larger (increasing energy maintenance cost) and as a result carcass relative weight will be lower and with a lower fat content. On grazing conditions even with forage of similar digestibility, dressing percentage could be affected by chemical composition of species. Steers grazing legumes will have a better dressing percentage than those on grasses due to a lower rumen fill (Thomson et al, 1991). Concentrate supplementation to grazing cattle will increase total dry matter and energy intake, reduce rumen fill, and consequently dressing percentage will be improved. When high quality pasture is not limited, ruminal fill and even animal finishing could be similar with or without supplementation but with medium to low quality forage or with limited pasture, energy supplementation will shorter finishing time and improve dressing percentage. On autumn grazing, dry matter intake decreases due to the low dry matter content of forage, therefore energy supplementation will definitely improve dressing percentage.

But not only carcass and organoleptic characteristics are important when defining beef quality. Nutritional value of meat is a fundamental aspect to be considered because consumers are becoming more concern about healthy diet, and there is a consensus against the consumption of animal fats. Beef is considered to be a food with high levels of saturated fat and cholesterol which has been seen by most medical opinions as one factor increasing the risk of the development of certain coronary heart diseases. It is one of the reasons that would explain the decrease in per-capita beef consumption occurring in developed countries in the last years. But not all beef have the same fat content and composition. Dietary lipid metabolism of cattle grazing high quality temperate pasture is different to that occurring in feed-lot cattle, and several studies have shown that beef produced on forage diet is leaner than beef produced on grain-fed systems (Crouse et al, 1984; Schroeder et al, 1980; Schaake et al, 1993; Bidner et al, 1986; Buchanan-Smith et al, 1991). It was also observed that meat from cattle on grazing have less cholesterol than the one derived from grain fed steers (García y Casal, 1992). Beside the muscle lipid content, its fatty acids composition is also different when steers are finished on all-grass diet. Beef lipids from cattle finished on pasture are rich in monounsaturated fatty acids and together with stearic acid sum more than 70% of non hipercholesterolemic fatty acid (Bonanome and Grundy, 1988).

Studies carried out on grazing conditions have shown that fresh forage from temperate pasture have a higher content and a different composition of lipids than hay, corn silage and starchy concentrate (Table 7). Besides its higher lipid content, fresh forage have a higher proportion of unsaturated fatty acids, mainly linolenic acid, compared to grain and conserved forage (Rearte, 1985; Gonda, 1989). Though most linolenic acid is partly or completely hydrogenated by rumen bacteria, small amounts escapes hydrogenation and is absorbed and converted to n^3 polyunsaturated fatty acid (PUFA). On the other hand, cattle on feed-lot receiving a grain diet are offered seed lipids containing mainly linoleic acid (n^2) with very little n^3 PUFA. Beef lipids from steers on grazing could be considered a source of n^3 PUFA.

The results presented and discussed until now have been about comparison of beef quality of steers finished on all-forage versus high grain diets in dry lot, but in reality these are not the most common practice applied by the majority of beef producer managing cattle on grazing. In the temperate region, pasture constitute the main component of cattle diet, grain is usually fed during the finishing period, not in a large amount in dry lot but in smaller quantity supplementing the grazed forage. To analyze the effects of pasture supplementation with grain, on carcass characteristics and beef quality, a trial was run by Rosso et al (1998) using steers grazing temperate pasture throughout the year and supplemented with corn grain. In this study, weaned aberdeenangus steers grazing high quality pasture were arranged at three treatments. One group of animals had pasture forage as the only component of the diet until slaughtered. Another group grazed the same pasture but was supplemented with corn at 1% BW during autumn and winter (A-W), and the third group was also on grazing but supplemented with corn at 1% BW during autumn and winter, interrupted in spring and supplemented again in summer (A-W-S) previous to slaughtered. A fourth treatment was included with steers fed a high grain diet in dry lot from weaned to slaughtered. Results are presented in Table 8.

As it was expected, steers on drylot had the highest daily gain, followed by the supplemented group. About carcass characteristics, dressing % was higher in drylot and A-W-S supplemented animals compared to all-pasture and A-W supplemented steers. Even when drylot steers had a higher performance and better carcass characteristics, compared to grazing steers (higher carcass weight, higher dressing % and higher rib eye area), those parameters were improved when grazing was supplemented with grain. On the other side, steers on grazing even when supplemented, had muscle with a lower content of fat than steer on dry lot. It was also important to detect a lower content of cholesterol in Longissimus muscle, a higher amount of n-3 linolenic acid and a lower n-6/n-3 linolenic ratio in beef from grazing steers. Linolenic acid from pasture would be the source for this conjugated unsaturated fatty acid in beef. The importance of those parameters relay on their incidence in reducing the risk of arterial coronary diseases. Carcass and palatability characteristics of beef produced on pasture with and without supplementation compared with that from drylot were also studied by Hedrick et al (1983). In this study grass-fed animals had carcasses with lower quality grades, marbling score, dressing percentage and fat thickness. Even when there was a trend for a lower tenderness, flavor and overall acceptability en beef from steers on grazing compared to those finished on dry-lot, it was enough self-feeding of corn on pasture for 67 days to equal carcass characteristics of drylot animals. When grain supplementation on pasture lasted 88 days previous to slaughter not only carcass but also sensory characteristics were similar to that obtained from dry lot steers.

Effects of supplementation on milk quality and processing characteristics - Although the effect of concentrate supplementation at pasture on milk production has been widely studied, little information exists on supplementation effect on milk composition and processing characteristics. In general, improving nutritional supply to the cow appears to improve the processing characteristics of the produced milk (Grandison et al, 1984).

The amount and type of protein in milk influences the yield and quality of products such as cheese, caseinate, and skim milk. Milk protein consists of a range of individual proteins which have different properties and are useful for manufacturing purposes in different ways. Casein proteins which represents on average 0.82 of the total milk proteins are synthesized entirely within the mammary gland (although Y-casein is exclusively formed from the enzymatic breakdowns of b-casein). These proteins are generally considered the most valuable for manufacturing purposes, particularly but not exclusively for cheese manufacture. The other 20% of milk proteins are the whey proteins, a group which includes both proteins synthesized de novo (80%) and proteins originating from the blood (20%). The ratios of casein:crude protein and casein:whey protein are also important manufacturing properties of milk. Increases in these ratios mean that for every unit of protein purchased by manufacturing companies, more casein will result, which will in turn increase the yield of casein-derived products such as cheese and caseinate. In the non-protein fraction urea is the main and most variable component and accounts for more than 90% of the seasonal changes in the heat stability of milk.

O´Brien et al, (1999) working with Frisian-Holstein cows grazing high quality pasture (81% OM digestibility, 23% CP) at different stocking rate, observed that energy concentrate supplementation increased total protein, casein and whey protein concentrations, but generally did not improve other processing characteristics except for ethanol stability. It is possible that the increase in casein concentration may not have been sufficient to alter the renneting properties, or there may not be a linear relationship between increased casein content and improved renneting characteristics. The FFA levels in milk were generally increased when grass supply was reduced by a high stocking rate and decreased by concentrate supplementation, showing that the concentration of FFA in milk decreases as the plane of nutrition increases. Free fatty acids levels and ethanol stability of milk have significant practical implications for manufacturers of short shelf life cheeses and cream liqueurs, therefore, it indicate that concentrate supplements would be required through the main grazing period if the standards for these product were to be met. From these studies it can be concluded that cows on grazing systems can support efficient production of high quality milk when adequate grass is available but if grass is scarce milk composition and processing characteristics will be adversely affected. In that case, concentrate supplementation would be recommended in order to increase the energy supply to cows.

In another trial the effect of concentrate supplementation on solid fat content at different temperatures and its consequences on butter characteristics were studied (Mackle et al, 1997). Under constant processing conditions there is a positive correlation between the solid fat content at 10ºC (SFC_{10}) and the sectility hardness of butter, which reflects the spreadability of the product. The SFC_{10} is related to the relative proportions of the different fatty acids in milk and to their configuration in the triglycerides. These authors concluded that supplementing pasture with rolled maize grain at 30% of total diet had minor effects on milkfat fatty acid profiles (increased C18:2 y decreased 18:3 provided by pasture), but did not affect SFC_{10} of milk.

Several studies have shown that cow diet can be responsible for differences in casein concentration of up to 10% (Petch et al., 1997). Nevertheless, Mackle et al, (1999) supplementing grazing cows with maize grain or corn silage reported no effects of supplementation on casein concentration. In this study, however other changes occurred in the proportion of different nitrogen component of the milk. Decreases in the ration of casein relative to whey, have been associated with product quality problems such as elevated cheese moisture and texture defects. In this study, there was a small increase in the ratios of casein:crude protein and casein:whey in the supplemented herd. Despite this, previous studies have shown that it is difficult to increase proportions of casein relative to whey by supplementing pasture with silage or grain. Anyway, in relative terms, the variation in whey protein was greater than the variation in casein protein, therefore an increase in casein:whey ratios might be most easily achieved by reducing whey protein, rather than increasing casein content.

Related to milk urea, its concentrations have been used as an indication of protein intake. This is consistent with the results obtained by O´Brien et al (1999) and Mackle et al (1999) in which both, NPN and urea were highest in the cows with the greatest proportion of pasture in their diet, and hence the highest crude protein intakes. NPN content was highest in cows on diets with a high protein to energy ratio, and lowest in cows on high energy diets. The practical relevance of the NPN fraction is that it represents the difference between crude protein and true protein, and variation in NPN can therefore introduce error into predicting true protein from crude protein, as is done by several commercial dairy companies. While energy supplementation generally increases true protein fraction in nitrogen milk (Castillo et al, 2000), protein supplementation generally had an opposite effect. Sutton et al, (1996) studied the effect of protein content in concentrates on milk nitrogen fraction in cows on grass silage diets, and concluded that as CP in the diet increased, proportion of true protein fell whilst non-protein nitrogen content increased correspondingly. At similar results arrived Castillo (1999) supplementing different level of fishmeal to dairy cows grazing alfalfa. In this case even when percentage of protein in milk remain unchanged, milk urea increased significantly as fishmeal content in the concentrate was augmented.

As conclusion it could be said that there is currently limited opportunity for dairy farmer with grazing systems to manipulate the composition of the N components in milk by supplementing different type of concentrate. The presented results emphasize that farm operators are more likely to achieve maximum profitability through yield of milk solids from their farms, rather that yield of an individual milk constituents.

Future research

Research on pasture supplementation has been a priority for years on grazing systems, and it will continue being in the future. Even when a lot of information was obtained on the effects of supplementation on animal performance, more research is needed on topics that are becoming more important every year. Grazing systems are continuously evaluated on its effects on environmental pollution because of the methane production, nitrogen contamination, etc.. Energy supplementation to cattle grazing high quality pasture not only would improve animal performance but it will diminish environment contamination by reducing the concentration of ammonium in rumen and consequently the excretion of urea through the urine (Astigarraga et al. 1993, Valk and Hobbelink, 1992). Type and level of concentrate, starch degradability, additive supplementation, etc, should have to be evaluated as a tool to control the environment contamination in the grazing production systems.

Even when daily weight gain, milk yield and conversion efficiency continue being important parameters of animal performance, carcass composition and beef quality would have to be evaluated in most supplementation trails because those are the product characteristics that the present market demands. Beef and milk produced on grazing in temperate regions have a composition with some nutritional advantages over the beef or milk produced in indoor systems based on concentrate. Beef and milk produced on pasture have a higher content of omega 3 linolenic acid and a lower n-6/n-3 linolenic ratio, important parameters in reducing the incidence and risk of arterial coronary diseases. Recently, it was also proved that beef and milk from pasture are the richest natural dietary sources of conjugated linolenic acid (CLA), which has been shown to have anti-cancer properties (Ha et al, 1987; Ip et al, 1991). Milk and beef quality and nutrient composition with potential health benefits will be the main characteristics demanded by the consumer in the near future. Concentrate supplementation on pasture will continue having the goal to enhance animal performance but it should be applied in a way that it will maintain the benefits and the properties of the product obtained from cattle grazing pastures.

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Table 1 - Rumen environment of cows grazing temperate pasture *(Rearte and Santini, 1993).*

	Forages			Rumen	
Species	**DM %**	**NDF %**	**CP %**	**NH_3 mg dl[1]**	**pH**
Oats	23	46	22	16	5.92
Lolium perenne	20	43	19	22	6.08
Medicago sativa	23	45	24	42	6.10
Lolium perenne (mature)	40	59	11	7	6.30
Fescue arundinacea	22	67	15	8	6.30
Agropirum elongatum	48	49	10	8	6.4

Table 2 - Ruminal digestion of cows grazing winter oats *(Elizalde et al, 1994, 1996).*

PERIOD	**A**	**EW**	**W**	**S**	**LS**
Date	**20/5**	**25/6**	**9/8**	**20/9**	**22/10**
Dry matter %	15.30	22.30	15.80	22.10	28.40
IVOMD[1] %	68.30	65.20	70.10	71.50	56.30
Neutral detergent fiber %	46.40	47.50	46.60	43.40	57.20
WSCHO[2] %	3.70	8.20	6.80	20.70	10.60
Crude protein %	23.10	21.20	21.90	11.70	10.30
Ruminal NH_3-N mg dl^{-1}	32.60	14.90	19.40	5.10	5.10
Microb.N g kg^{-1} OMDR[3]	24.6	32.4	30.1	27.9	32.6

[1] In-vitro organic matter digestibility
[2] Water soluble carbohydrate
[3] Organic matter digested in rumen

Table 3 - Forage digestion, rumen environment and N metabolism on supplemented heifers *(García et al, 2000).*

	Only oats forage	Barley	Corn
Digestibility OM, %	81.5	81.2	81.6
N intake, g/d	320[a]	222b	273c
Rumen NH_3, mg/dl	29[a]	19b	27[a]
N flow to duodenum			
Total N, g/d	184	160	178
Ammonia N, g/d	5.3[a]	2.7b	2.7b
Non ammonia Nm g/d	161	142	158
Bacterial N, g/d	102	102	94
Non bacterial N, g/d	59	40	64
g BN/kg OMADR	25.4	28.2	22.7

[a,b,] Numbers with different letters differ significantly

Table 4 - Diets composition, rumen digestion and milk production and composition of grazing cattle supplemented with concentrate of different rumen degradability

	Diet composition		**Rumen digestion**			**Production**		
Treatments	**Pasture Kg/d**	**Suppl. Kg/d**	**PH**	**NH3 mg/dl**	**AGV Mmol/l**	**Milk l/d**	**B.F. %**	**Prot. %**
Dry grounded corn	11.5*	6.18	5.7	11.2a	76	20.17	3.90	3.11
Steam flaked corn	9.8*	6.64	5.6	8.0b	72	20.95	3.71	3.10
** 50% corn silage, 50% pasture*								*Bargo et al, 1998*
Dry grounded sorghum	12.4	6.2		26.6a	88	20.22	3.35	3.17
Steam flaked sorghum	14.3	6.2		20.6b	88	20.80	3.23	3.20
								Pieroni et al, 1999
Dry grounded corn	14.83	5.6	5.97	19.1a	90	17.24	3.13	3.30
High moisture corn	14.60	6.4	6.01	12.9b	86	17.61	3.29	3.39
								Alvarez et al, 1993
Control non supplemented	13.4	0.8	6.0	19a	127	19.3	4.1	3.3
High starch suppl.	11.3	5.4	5.9	13b	127	20.0	3.8	3.5
Low starch suppl.	12.8	5.2	5.9	12b	130	18.9	4.1	3.3
								Van Vuuren et al, 1986

[a,b,] Numbers with different letters differ significantly

Table 5 - Supplementation with protein of different ruminal degradability to grazing dairy cows.

Treatments	Intake, kg DM/d		Production		
	Pasture	Suppl.	L/d	BF, %	Prot. %
Control, 0 fish meal	8.8	7.0	29.5	3.37	3.01
0.5 kg/d fish meal	9.9	7.0	29.6	3.33	2.99
1.0 kg/d fish meal	10.1	7.0	29.7	3.28	3.0
1.3 kg/d fish meal	9.9	7.0	28.4	3.35	3.03
					Castillo et al, 1999
Sunflower meal		6.0	22.2	3.45	3.00
Meat meal		6.0	22.5	3.35	2.95
					Rearte et al, 1989b
Sunflower meal	16.6	4.4	25.4a	3.22	3.19
Fish meal	17	4.4	27.5b	3.32	3.28
					Schroeder et al., 1998
Soybean meal	13	6	22.5a	3.1	2.83
Blood meal	17	6	26.8b	3.2	2.84
					Schor et al., 1996
Sunflower meal 15% CP	12	6.3	19.5	3.46	3.56
Sunflower meal 18% CB	14.3	6.5	20.8	3.35	3.30
Feather meal 18% CB	13.2	6.5	21.2	3.57	3.31
					Bargo et al., 1997
Sunflower meal	13.85	6.95	23.96	3.47	3.29
Roasted soybeans meal	19.52	6.95	22.94	3.61	3.24
					Piñeriro et al., 2000
Concent., 0 roasted soybeans		8.0	28.1	2.96	3.06
Concent., 18% roasted soybeans		8.5	28.7	3.18	2.90
Concent., 36% roasted soybeans		8.3	27.8	3.20	2.85
					Dhiman et al, 1997
Concent. High RUP	12.0	8.9	35.5	3.29	2.87
Concent. Low RUP	11.0	8.9	34.2	3.53	2.89
					Hongerholt and Muller, 1998

a,b, significantly different , $P<0.05$.

Table 6 - Carcass and organoleptic characteristics of meat form steers grazed on high quality alfalfa/grass pastures and finished on grain on 0, 33 or 75d *(McCaughey and Cliplef, 1996).*

Parameters	**Pasture Only**	**33 d barley**	**75 d barley**
Liveweight and carcass data			
Post-shipping liveweight, kg	542.1c	588.3b	633.0a
Dressing, %	56b	58[a]	58[a]
Grade	1.9[a]	1.0b	1.0b
Rib eye area, cm2	76.4b	89.3[a]	91.4[a]
Rib eye color, 1-6	3.3[a]	2.1ab	1.8b
Rib eye marbling, 1-10	2.5	2.9	3.0
Fat color, 1-3	2.1	2.0	2.0
Taste panel ratings, 1-10			
Tenderness	7.2	6.8	6.7
Juiciness	7.2	7.0	7.5
Flavor	7.4	6.9	7.4
Chemical analysis			
Fat, %	2.6	2.5	3.1
Protein, %	22.2[a]	22.2[a]	21.7b

[a,b,] Numbers with different letters differ significantly

Table 7 - Lipid content and fatty acid composition of different feedstuffs *(Rearte, 1985).*

		Fatty Acids in lipid, % by weight				
Feed	**Lipid %DM**	**$C_{16:0}$**	**$C_{18:0}$**	**$C_{18:1}$**	**$C_{18:2}$**	**$C_{18:3}$**
Pasture	5.3	15	2	3	13	67
Grain	3.6	14	3	29	52	2
Corn silage	2.5	18	5	25	48	4
Alfalfa hay	3.3	32	5	6	22	35
Haylage	3.7	29	6	10	24	31

Table 8 - Animal performance, carcass characteristics and beef quality of grazing steers supplemented with corn grain *(Rosso et al, 1998).*

Parameter	**Pasture**	**Pasture + Sup A – W**	**Pasture + Sup A – W - S**	**Drylot**
Animal performance				
Total ADG, kg/d	0.706^{a}	0.839b	0.773b	1.190c
ADG A-W, kg/d	0.427^{a}	0.822b	0.858b	1.018c
ADG spring, kg/d	0.926^{a}	0.815b	0.730b	1.085c
ADG summer, kg/d	0.768	0.739	0.766	
Slaughter BW, kg	444	456	452	458
Slaughtered steers at 216d, %	0	0	0	100
Slaughtered steers at 294d, %	25	65	74	0
Slaughtered steers at 329d, %	75	35	26	0
Carcass characteristics				
Carcass weigh, kg	243^{a}	253^{a}b	259bc	265c
Dressing, %	54.82a	55.35^{a}	57.46b	57.84b
Fat thickness, mm	7.3^{a}	6.3^{a}	7.3^{a}	9.9b
Cuarto pistola weigh, kg	46.8^{a}	51.3b	52.4b	46.8^{a}
Quality and chemical composition				
Tenderness,	10.16	9.84	8.99	7.68
Rib eye area, cm^2	57.5^{a}	63.0ab	67.0b	76.9c
Semitend.Intramuscular fat, %	2.0a	2.5^{a}	2.4^{a}	3.2b
Longissim.Intramuscular fat, %	2.2^{a}	2.6^{a}	2.9^{a}	4.7b
Semitend. Cholesterol, mg/100g	39.5	42.3	42.7	40.7
Longissim. Cholesterol, mg/110g	45.5^{a}	45.9^{a}	45.9^{a}	52.8b
Linolenic n-3 acid,	1.37^{a}	1.07ab	0.68b	0.19c
Linolenic n-6/n-3 ratio	2.3^{a}	2.75^{a}	5.46b	21.9c

[a,b,] Numbers with different letters differ significantly

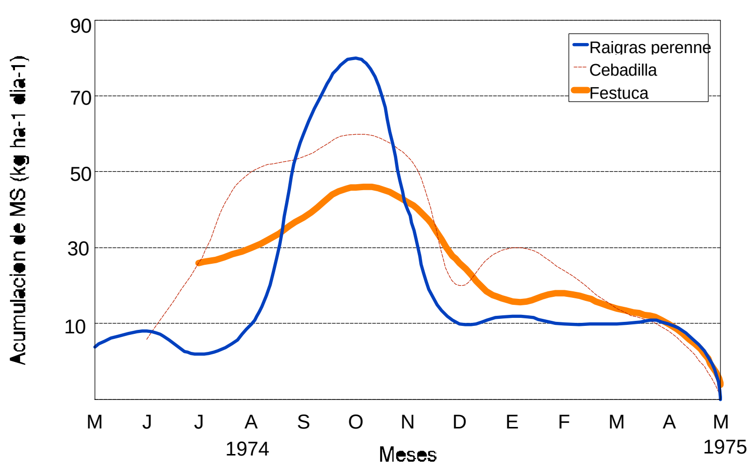

Figure 1 - Grasses production curve in Buenos Aires province in Argentina (*Santini et al. 1975).*

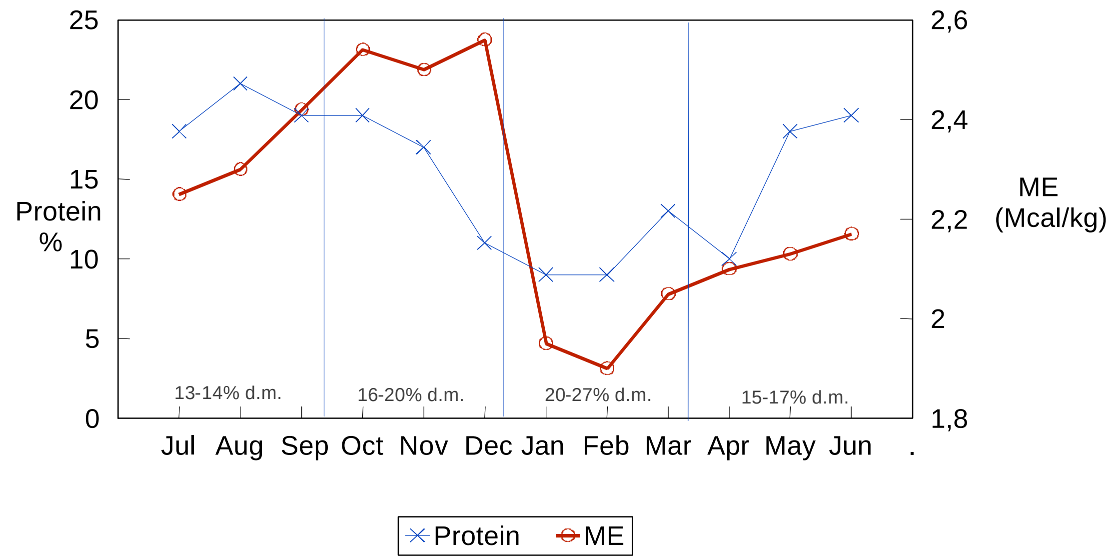

Figure 2 - Protein and energy content in fertilized pastures of south of Chile *(Anrique y Balocchi, 1993).*

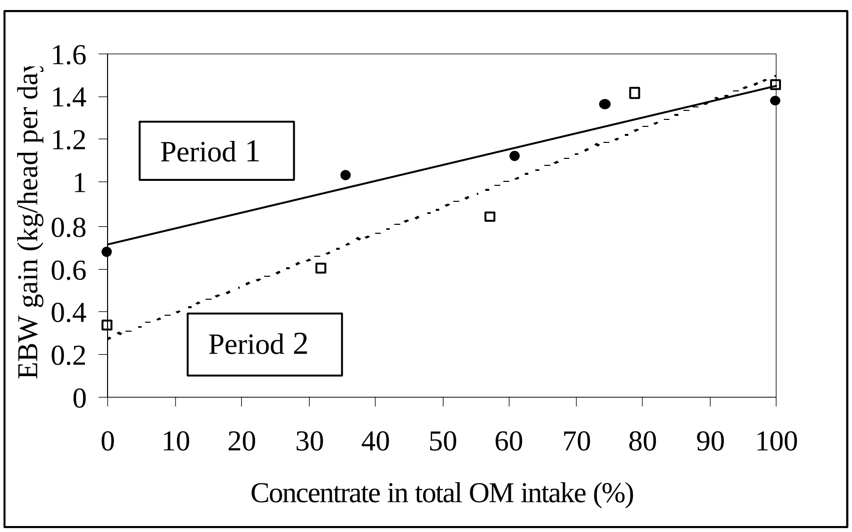

Figure 3 - Relationship between empty body-weight gain and proportion of concentrate in the diet *(Adaptaded from Tayler and Wilkinson, 1972).*