Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP5: 269-275

AM Ganai
Division of Animal Nutrition, F.V. Sc & AH, Shuhama, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

Zulfiqarul Haq
Division of Animal Nutrition, F.V. Sc & AH, Shuhama, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

YA Beigh
Division of Animal Nutrition, F.V. Sc & AH, Shuhama, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

GG Sheikh
Division of Animal Nutrition, F.V. Sc & AH, Shuhama, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

Correspondence
AM Ganai
Division of Animal Nutrition, F.V. Sc & AH, Shuhama, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

(Special Issue- 5)
International Conference on
"Food Security through Agriculture & Allied Sciences"
(May 27-29, 2019)

Bypass nutrient technology with recent advances for enhancing animal production: A review

AM Ganai, Zulfiqarul Haq, YA Beigh and GG Sheikh

Abstract
Feed inadequacy is a major impeding factor responsible for lower productive animals in India than world average, resulting in least explored genetic potential with lower genetic gains and inefficient selection. From past few decades more growth in animal number has been observed than per unit productivity, leaping more pressure on already stressed nutritional resources available in India. Crop residues form the bulk of feed resources in India which are of inferior quality. Oil seed cakes are not suffix due to their lower production and partly due to their export to other countries. Further efforts to increase the efficiency of nutrient utilization is a double pronged approach as it increases animal production along with imparting less stress on already bleak nutritional resources. Bypass nutrient technology is emerging as an important nutritional tool to increase the productivity of animals. Bypass nutrients (mainly fat and protein) are protected from hydrolysis in rumen which gets absorbed from the lower digestive tract without altering rumen environment. The other protected nutrients are protected starch, chelated minerals and vitamins. This review will bring forth previous and recent advances in manufacturing, ingredients and results incurred through bypass nutrient technology for improving animal productivity in existing conditions of India.

Keywords: Bypass nutrients, India, protected nutrients, efficiency

Introduction

Livestock production contributes significantly to rural economy and in developing countries of the world feed inadequacy is a major impediment in exploiting genetic potential of animals for milk, meat & wool production (FAO, 2019) [14]. There is horizontal growth in terms of animal numbers but to achieve vertical growth in terms of improving productivity is the need of hour. In tropical countries majority of livestock subsist on poor quality native grasses, crop residues and agro-industrial byproducts (Shankhpal *et al.*, 2016). Therefore it is a big challenge to meet the nutritional requirements of high yielding and genetically improved animals. One of the promising ways to address this issue is through protected nutrient technology, by which the dietary nutrients (fat and protein) are protected from hydrolysis, allowing these nutrients to bypass rumen (Shelke *et al.*, 2012) [47, 48]. These nutrients get digested and absorbed from the lower digestive tract. The other protected nutrients are protected starch, chelated minerals and vitamins.

In an attempt to extract more or increase the efficiency in absorption of the existing feed resources, protecting various nutrients from microbial degradation in rumen so that they are available for absorption elsewhere down the gut is viable option known as bypass nutrients (Walli 2005) [39]. Various protected nutrients studied and used in livestock sector include; protected proteins/amino acids, protected fat, protected starch and chelated minerals and vitamins (Shelke *et al.*, 2012) [47, 48]. Apart from nutrients, various drugs, medicaments and diagnostics are being studied and experimented for bypass and protection to enhance their bio availability.

Protected/bypass Protein

Protein that is not degraded in the rumen and reaches the small intestine unmodified is called rumen bypass protein. Supplementation of this type of protein can improve productivity in terms of improved efficiency of meat, milk and wool production (Anonymous, 2019) [2].

Various methods have been used for protecting proteins from rumen degradation, such as heat treatment and formaldehyde treatment. These methods are thought to act either by inhibiting proteolytic activity or by modifying protein structure in such a way that the number of protease specific bonds that can be cleaved by microbial enzymes is decreased (Walli, 2005) [39].

Methods of protein protection

Several methods have been used from the inception of bypass protein technology which includesophageal groove closure using orally the salts of Cu, Ag, Na and Zn (Orskov and Benzie, 2001) [34]. Tannic acid has also been used by many workers owing to its greater affinity for protein to form a rumen insoluble complex which can be hydrolyzed in acidic pH only (Hatfield, 2007) [18]. Newer techniques which have been added are lipid protected products, carbohydrate surface coated products, lipid/pH sensitive polymer coated products and use of analogues many limiting amino acids (methionine & lysine). Analogs (met hydroxyl analog 2-hydroxyl-4-methylthio butanoic acid-HMB) and methionine derivatives (isopropyl-DL-met, t-butyl-DL- met) have been used as bypass amino acid sources (Sirohi *et al*., 2005) [49].

Much of work on bypass proteins has been carried out on formaldehyde (HCHO) and heat treatment of highly degradable cakes. Heat treatment may not be cost effective and it can also overprotect the protein (Sengar and Mudgal, 1992) [27]. It is a combination of heat and time which decreases rumen solubility of proteins by creating cross linkages both within or among peptide chain or to carbohydrates however prolonged high temperature induces Maillard reaction (Sirohi *et al*., 2005) [49]. Walli (2005) [39] reconsidered the heat treatment of GNC and soybean cake at 150 ^{0}C for 2 hours as the optimum temperature time combination. HCHO treatment has been used by many workers in India to reduce rumen degradability of high degradable cakes and also to study the impact of its feeding on various performance traits of ruminants (Ganai *et al*., 2008; Shelke *et al*., 2011). Chatterji and Walli (2003) [5] treated protein meals directly with formalin using it @ 1.2g/100g CP for optimum protection of mustard and groundnut cake and after treatment the cake was kept under airtight condition in polythene bags for few days. This leads to formation of rumen pH resistant methylene bridges between amino group of protein and aldehyde group of HCHO (Walli 2005) [39].

Effect of bypass protein on rumen fermentation, milk, weight gain, wool growth and economics

The concentration of rumen pH and ammonia nitrogen were found to be lower in a concentrate mixture of higher undegradable protein (UDP) level of 63.38%as compared to the medium level of 47.55% and low UDP levels of 29.75%.Chatturvedi and Walli (2002) [6] observed that by increasing the quantity of UDP and by decreasing the quantity of total CP even upto 20% of NRC (2001) [32] in the diet of ruminants, the rumen pH and nitrogen fractions remained optimum while as the volatile fatty acid concentration was below the normal due to decreased rumen fermentation rate. By feeding naturally occurring protected proteins like cotton seed cake and maize gluten meal to the lactating ruminants yielded positive results (Walli, 2005; Ramchandran and Sampath, 1995) [5, 37]. Garg *et al*., (2003) [16] while comparing the effect of naturally protected protein (30% UDP) and HCHO processed sunflower oil seed meal supplement (optimal bypass with 75% UDP) in crossbred cows found a significant increase in milk yield, milk fat and milk protein percent. Sampath *et al*. (1997) [41] observed significantly higher FCM yield in lactating crossbred cows fed with formaldehyde treated GNC (7.8 Vs 9.4 kg/day). Chatterji and Walli (2003) [5] found significant increase in the milk and FCM yield of medium milk producing buffaloes fed with HCHO treated mustard cake. Walli and Sirohi (2004) [57] also reported 15% increase in milk yield on feeding of HCHO treated mustard cake to crossbred cows. Shelke *et al.*, (2011) found significant increase in the milk yield and milk fat of the lactating murrah buffaloes by the supplementation of protected nutrients, hence giving higher profits. Sahoo and Walli (2001) [39] found that by feeding HCHO treated GNC to the goat kids generally increase their growth rate. Chatterjee and Walli (2003) [5] obtained a highly significant increase in growth rate of buffalo calves (55% increase over control group) fed HCHO treated mustard. Yadav and Chaudhary (2010) [58] observed significant increase in growth rate of crossbred heifers fed HCHO treated GNC. An average daily weight gain of 537.71g with protein protected diet was found in growing buffalo heifers as compared to 398.31 g with control diet (Patel *et al*., 2012) [36]. Average greesy weight and clean wool yield showed significant increase in Nalilambs fed HCHO treated Mustard oil cake (Ganai and Sharma 2008) [15]. According to Medhi *et al*., 2014 [26] there was significant improvement in production of clean wool in treatment group with HCHO treated mustard oil cake in coriedale lambs. Bypass protein feeding has yielded encouraging results in terms of gains harvested in milk quantity and quality, body weight and wool growth. The net profit and earnings are better and well justified. Garg *et al*., (2003) [16] reported an increase by Rs.6.49/animal day with the protected rapeseed feeding. Bughalia and Chaudhary (2010) [58] worked out an average feed cost per kg milk production upon feeding bypass protein (HCHO treated sesame cake) at Rs. 5.92 against Rs.6.32 with an untreated protein.

Protected/ Bypass fat

During early lactation the high producing dairy animals remain in considerable negative energy balance leading to metabolic stress manifested as fall in milk production, fertility disorders and poor body condition (Drackley, 2009) [12]. The energy intake through ration doesn’t meet the requirement for higher milk production (Shelke *et al.*, 2011). Conventionally by increasing the dry matter intake through feeding would be the choice but the risks are manifold as by doing so would decrease the fiber intake which will lead to acidosis and milk fat depression (Jenkins and McGurie, 2006). Although dietary fat has great potential to enhance energy density of the ration and the composition of the milk fat but its use in large amounts is limited by various factors.

Due to the high extent of dietary fat hydrolysis in the rumen (85-95%) a considerable reduction in fiber digestibility occurs. Devendra and Lewis (2005) [11] explained four the Orison this reduction of fiber digestibility by dietary fat, which include (i) coating of the fibrous portion of the diet with the lipids thereby preventing attack by the microorganisms(ii) modification in the rumen population concerned with the cellulose digestion (iii)inhibition of the activity of the rumen microorganisms due to an effect on cell permeability brought about by absorption of the fatty acids on cell wall or due to an anti-metabolite effect (iv) reduction in the availability of minerals (Ca and Mg) essential for the microbial activity due to the formation of mineral complexes with the fatty acids. Role of the bypass fat in the rations of the high producing dairy animals is very crucial for enhancing the energy density of ration (NRC, 2001) [32]. Dietary fat, that resists lipolysis and biohydrogenation in rumen by rumen microorganisms, but gets digested in lower digestive tract, is known as bypass fat or rumen protected fat or inert fat.

Natural bypass fat

Whole oil seeds when fed unprocessed except drying have natural bypass fat properties due to their hard outer seed coat which protects the internal fatty acids from lipolysis and bio hydrogenation in rumen. However, mastication causes physical breakdown of seed coat rendering it easily accessible to rumen microbes (Ekeren *et al*., 1992) [13]. Important whole oil seeds commonly used in the ration of dairy animals are cotton, roasted soybeans, sun flower and canola. Furthermore, feed ingredients containing saturated fatty acids are less toxic to the ruminal microorganisms and minimize the adverse effects of the fat supplementation as they react more readily with the metal ions forming insoluble salts in rumen and do not go for further ruminalbio hydrogenation (Chalupa *et al*., 1998) [4].

Chemically prepared bypass fat

Chemically prepared bypass fat mainly includes crystalline or prilled fatty acids, formaldehyde treated protein encapsulated fatty acids, fatty acyl amides and calcium salts of long chain fatty acids (Ca-LCFA).Crystalline or prilled fatty acids can be made by liquifying and spraying the saturated fatty acids under pressure into cooled atmosphere so that the melting point of the fatty acids is increased and do not melt at ruminal temperature thus resisting rumen hydrolysis and association with bacterial cells or feed particles (Chalupa *et al*., 1998) [4]. Formaldehyde treated protein encapsulated fatty acids is also an affecting means of protecting dietary fat from rumen hydrolysis (Sutton *et al*., 2000) [53]. Oil seeds can becru shed and treated with formaldehyde (1.2 g per 100g protein) in plastic bags or silos and kept for about a week. Fatty acyl amide can be prepared and used as a source of bypass fat. Butylsoyamideis a fatty acyl amide consisting of an amide bond between soy fatty acids and a butyl amine, which increases linoleic acid content of the milk fat. Conversion of oleic acid to fatty acyl amide (oleamide) increases the mono-unsaturated fatty acids concentration of the milk, when fed to dairy cows. Amide of soybean is effective in enhancing the post-ruminal flow of oleic acid (Lundy *et al.*, 2004) [23]. Fatty acyl amide of sardine oil based complete diet is effective in protecting fat from degradation in rumen and improves the apparent and true dry matter degradability (Ambasankar and Balakrishnan, 2011). Calcium salts of long chain fatty acids (Ca-LCFA) are insoluble soaps produced by the reaction of carboxyl group of long chain fatty acids (LCFA) and calcium salts (Ca^{++}). Degree of insolubility of the Ca soaps depends upon the rumen pH and type of fatty acids. As the dissociation constant (pKa) of Ca-LCFA is 4 to 5 hence dissociation is significant when pH decreases to6.0 (Chalupa *et al*., 1998) [4]. In acidic pH of the abomasum, fatty acids are dissociated from Ca-LCFA and then absorbed efficiently from small intestine. The unsaturated soaps are less satisfactory for maintaining normal rumen function, because dissociation is relatively higher (Sukhija and Palmquist, 2002) [52]. Among all forms of bypass fat, Ca-LCFA is relatively less degradable in rumen and has highest intestinal digestibility hence serving an additional source of calcium (Naik *et al*., 2007) [29]. In India, most of the dairy farmers are small and marginal (Sharma, 2011) [46] and often bypass fat is out of reach to them due to its inadequate accessibility or high cost. To make the bypass fat more accessible to all types of dairy farmers, a simple cost effective indigenous technology has been developed for the preparation of bypass fat (Ca-LCFA) using different vegetable fatty acids and significant works have been conducted by several workers (Gowda *et al*., 2013) [17].

As per NRC (2001) [32], dairy ration (mixture of cereals and forages) contains about 3% fat and the total dietary fat in ration should not exceed 6-7% of the DM. Bypass fat can be included in higher amounts in the diet of dairy animals but feeding bypass fat at 9% of the DM is not beneficial in lactating dairy cows (Schauff and Clark, 1992) [42, 43]. Palmquist (2007) [35] suggested that the first 3% fat of the DM intake of the animal should be provided by oilseed sources and that in excess of 3% should be as bypass fat. It is recommended that ration of the high producing animals should contain 4-6% fat, which should include fat from natural feed, oil seed and bypass fat in equal proportions. In Indian feeding condition, about 200-300g bypass fat product has been supplemented in the daily diet of the lactating crossbred cows by many workers (Mudgal *et al.*, 2012) [27]. However, other workers supplemented bypass fat @ 2.5% and 4.0% (Thakur and Shelke, 2010) [54] of the total DM intake of the lactating crossbred cows and buffaloes, respectively.

Effect of bypass fat supplementation on rumen fermentation, milk composition, weight gain, reproductive performance and economics

The TVFA concentration was found to be lower in the diet without bypass fat as compared to the diet with bypass fat (Naik *et al*., 2007) [29]. Schauff and Clark (1992) [42, 43] concluded that an increase in the level of bypass fat, ruminal fluid pH and concentration of TVFA did not change but molar percentage of acetate and acetate to propionate ratio increased linearly. Saijpaul *et al*. (2010) [40] reported that an indigenously prepared bypass fat can substitute up to 40% of the natural fat of the concentrate mixture or upto6% natural fat contained in total mixed rations. Dietary supplementation of the indigenously prepared bypass fat (Ca-LCFA) was found to have no adverse effect on the rumen fermentation of buffaloes fed wheat straw based diets (Naik *et al*., 2010) [40].

Mudgal *et al.*, 2012 [27] reported that the DM intake (7.44-12.54 vs 7.65-13.60, kg/ d) of dairy animals was not altered by supplementation of bypass fat. However, Chouinard *et al*. (1997) [7] reported decrease (23.5 vs 21.5, kg/d) and Tyagi *et al.* (2009) [5] reported increase (3.16 vs 3.41; kg/100 kg BW/d) in DM intake in dairy animals fed with bypass fat. To overcome any palatability problem with bypass fat grain dilution method is suggested. Due to non interference and relatively stable nature of bypass fat, no effect of supplementation of bypass fat on the digestibility of DM, OM, CP, CF, NFE, NDF and cellulose was found (Sirohi *et al.*, 2010) [50]. According to Thakur and Shelke, 2010 [54] digestibility of either extract increased significantly when bypass fat was supplemented in the diet of the dairy animals. This increased fat digestibility indicates that bypass fat is more digestible than the basal diet fat resulting in accurate estimate of the true lipid digestibility. However, lowering of fat digestibility at higher level of supplementation may be due to the limited capacity of the small intestine to absorb the fat.

According to many reports a significant increase by 5.5-24.0% in the milk yield of the dairy animals was observed when fed with supplemented bypass fat (Gowda *et al*., 2013; Wadhwa *et al*., 2012) [17, 56]. Although, there is no significant interaction with breed of cow, effect of supplemental by pass fat (Ca-LCFA) on milk yield tends to be greater in Holstein cows than Jersey cows. Stage of lactation influences supplemental effect of the bypass fat on milk yield and FCM yield which is generally increased in early and peak lactation, may be due to the higher energy intake, more efficient use of fat by mammary gland and enhancement of tissue mobilization before peak production. Schauff and Clark, 1992 [42, 43] reported that an increase in FCM yield of lactating cows when Ca-LCFA was supplemented up to 6% of the dietary DM and recorded a decreased at 9% of the dietary DM.
Among all the components of milk, fat content is most sensitive to the dietary changes. Unlike the milk yield, although there is no significant interaction with breed of cow, effect of supplementation of Ca-LCFA on milk composition tends to be greater in Holstein cows than Jersey cows. Addition of bypass fat in diet generally increases the total milk fat yield due to increase in the milk production (Naik *et al.*, 2007) [29]. Milk fat percentage and yield decreases linearly with increase in the amount of dietary Ca soap and Ca-LCFA from a saturated fat source have little influence on milk fat content (Chouinard *et al*., 1997) [7], while an increase in unsaturation of dominant FA in Casalts has a positive linear effect on the milk fat percentage of lactating cows (Chouinard *et al*., 1998) [8]. Supplementation of Ca-LCFA in the diet of lactating cows generally decreases the proportions of short and medium chain saturated fatty acids (C6:0 to C16:0) of milk fat due to reduction in *de novo* FA synthesis in mammary gland and increase in proportions of LCFA (C18:1, C18:2, C18:3) due to increased uptake of preformed LCFA from blood (Mishra *et al*., 2004).
The SNF content of milk is either not altered or increased, however the total SNF yield is increased due to the increase in milk production (Wadhwa *et al.,*2012) [56]. Milk protein is more responsive to diet than lactose but is less responsive than fat. Generally, supplementation of bypass fat (Ca-LCFA) has negative effect on the milk protein percentage an overall effect of -0.12 percentage unit due to the dilution of milk protein as higher milk volume synthesized is not synchronized with uptake of amino acids by the mammary gland (De Peters and Cantt, 1992) [10].
Supplementation of Ca-LCFA in the diet has positive effect on reproductive performance of dairy cows which is further dependent up on the specific fatty acids profile of the Ca salt. Feeding Ca-LCFA increases pregnancy rate and reduces open days. Several hypotheses are suggested regarding role of the fatty acid son reproductive performance of dairy animals (Sklan *et al*., 1994) [51]. These include (i) improved energy balance results in an earlier return to post-partum ovarian cycling; (ii) increase linoleic acid may provide increase PGF2α and stimulate return to ovarian cycling and improve follicular recruitment; and (iii) increase in progesterone secretion either from improved energy balance or from altered lipoprotein composition from dietary fat improves fertility. Gowda *et al.* (2013) [17] also reported better reproductive per formance in cows fed indigenously prepared bypass fat. The reproductive performance in Murrah buffaloes along with an increase in the milk production and its persistency improved when supplemented by protected fat and protein during early lactation (Shelke *et al.*, 2012) [47, 48].

The cost of production of the indigenously prepared bypass fat depends upon the cost of the raw materials. Depending upon the accessibility of raw materials, cost of production of the bypass fat prepared by the indigenous technology is reasonable and affordable. Feeding of the indigenously prepared bypass fat to dairy animals has shown to give additional profit of Rs. 34.50/- per cow per day, Rs. 11.60/ - per cow per day and Rs. 39.66/- per buffalo per day (Gowda *et al*., 2013) [17] besides there was an improvement in the reproductive performance and health of the animals.

Bypass Starch/ Rumen Resistant Starch:
In high producing ruminants such as dairy cows or feedlot cattle the energy requirements are high to support high milk yields and rapid weight gains. Therefore, these intensive management systems typically encourage the inclusion of large amounts of easily degradable carbohydrates in the diet to support a high performance and enhance cost efficiency (Nocek, 1997) [31]. The most common cereal grains used in ruminant nutrition are barley, maize, and wheat. In contrast to maize, barley grain is rich in rapidly fermentable starch, resulting in a more rapid accumulation of short chain fatty acids (SCFA) in the rumen fluid (Ascenbech *et al.,* 2011). For instance, depending on the amount of dry matter ingested the rumen of dairy cows may generate up to120–130 mol (6–7 kg) SCFA daily, in which is almost 70% of the energy is supplied to the host. This load of SCFA leads to acidotic conditions in the rumen commonly known as subacuteruminal acidosis (SARA). If the ruminal pH drops as low as around pH 5 this eventually results in an acute ruminal acidosis (ARA) (Ngaraja *et al*., 2007). ARA and SARA are severe metabolic diseases in cattle associated with impaired digestion, frothy bloat, laminitis, liver abscesses, and polioencephalomalacia (Karapinar 2010) in cattle. During the last two decades, a large number of studies have examined ways to modulate the rumen degradability of typical cereal grains aiming to improve the feed efficiency of cattle by altering the nature and amount of the starch available to rumenmicrobiota, and hence shifting some starch digestion to the small intestine. Many attempts have been made to develop grain processing technologies to promote the animal's performance and feed utilization but without impairing animal health. Physical and thermal treatments of grain in relation to performance in cattle have been reviewed more often than the chemical processing techniques (Dehghan Banadaky *et al*., 2007) [9].

Chemical grain processing methods
Chemical grain processing methods employ various chemical substances aiming to change the starch structure and hence their degradation characteristics. As compared to the mechanical, the rmal processing techniques, the chemical methods have advantages because they are cheaper. The advantages of treating grain with chemical substances were observed with the use of sodium hydroxide (NaOH) which resulted in a slower ruminal starch degradation as well as a decreased susceptibility to rumen acidosis and increased the whole tract digestibility (Schmidt *et al.,* 2006) [44]. However, sorghum treated with Na OH showed a reduced total starch apparent digestibility when measured in the entire gastrointestinal tract (Dehghan Banadaky *et al.*, 2007) [9].
Besides NaOH, formaldehyde (HCHO) is another chemical that has been extensively used to treat grains. In a study conducted by Martínez *et al*. (2008) [25], 40 goats were fed a

wheat based diet protected with5% HCHO and mixed with 15% saponified tallow. From the analysis it was found that the numbers of follicles were enhanced in the goats fed with formaldehyde treated wheat when compared to the control group hence indicatinga better energy supply and metabolic health status of the animals. In fact, the authors concluded that the follicle development was stimulated by RRS reaching the duodenum and the subsequent glucose supply which was apparently increased by this chemical treatment. An increased glucose supply enhances the insulin level thus influencing the gonadotropin secretion or the follicles directly (Leroy *et al*., 2008) [22].

New grain processing methods and their potential metabolic effects

There is an impending interest in detecting new chemical grain processing techniques such as treating grain with mild acids in order to modify starch degradation. Only a few experiments were conducted under *in situ* and *in vivo* conditions in ruminant nutrition so far (Iqbal *et al*., 2012) [19] hence there is scarcity of information and further studies are necessary. Lactic acid bacteria and their metabolized product, lactic acid (LA) have been used for fermentation and preservation of food for centuries in dairy (Yu *et al*., 2011) [59] or non-dairy fermented products (Rhee *et al*., 2011) [38]. However, only recently the research indicated interest to use LA as a modifier of the cereal grain starch as it has an ability to slow the enzymatic action of amylases of grain which ledto a decrease in degradability of starch in human and *in vitro* studies (Ostman *et al*., 2002). However, an exact mode of action of LA on starch structure is currently not fully understood. One possibility could be that LA causes linearization of the branched amylopectin molecules and hence limits the enzymatic attack. Though barley is richin energy and protein and an excellent feed grain for ruminants but feeding barley grain often leads to digestive and metabolic disorders because of high incidence of SARA which is due to the rapid fermentation rate of barley starch. Between 80% and 90% of barley starch, but only 55% to 70% of maize starch is degraded in the rumen (Offner *et al*., 2003) [33].

Organic acids are naturally found in biological tissues or produced in the gastrointestinal tract and are generally used to modify rumen fermentation. Among the mfumaric, malic, and aspartic acids were frequently used acids in ruminant nutrition (Jalc *et al*., 2002). Fumarate and malate are intermediate products of the citric acid cycle, as wellas intermediates in the succinate propionate pathway of *Selenomonas ruminantium*, predominant in the rumen ecosystem and known to stimulate proprionate production and increase pH value because of its potential to increase the uptake and utilization of lactic acid. The most promising additive is malate which has several benefits such as increasing DM digestibility, decreasing methanogenesis, and uncomplicated application (Khampa and Wanapat, 2007) [21]. However, due to the high costs of malic acid, this feed additive is not the best choice with regard to the farmer's budget.

Tannins are naturally occurring secondary plant constituents, suggested as a means to slow down ruminal starch degradation. Tannic acid is known to bind to protein and fiber components may also form complexes with starch and therefore could be apromising tool for protecting starch from ruminal degradation. However, since only limited data (*in situ* studies) exist about the potential role of TA on rumen degradation of barley an intensive *in vivo* research is warranted to validate these *in situ* data before conclusions for practical use can be drawn (Martínez *et al*., 2005) [24].

Conclusion

Several assessments have agreed that there will be drastic increase in the demand for livestock products in developing countries, driven largely by human population growth, income growth, urbanization and a further shrink in fodder cultivation land by human population. This will further limit the already scarce nutritional resources available to animals in India demanding immediate nutritional interventions from time to time. From the review it can be concluded that bypass nutrient technology is a very promising tool available and will help to improve feed efficiency with more genetic gains. Bypass protein are undegradable at rumen level and maximizes the quantity of amino acids absorption in intestines to support growth and yield. Supplementation of bypass fat in the diet of animals has proven very useful to increase milk yield, FCM yield, efficiency of nutrient utilization, postpartum recovery of the body weight, body condition score, reproductive performance and alleviate problems of negative energy balance without adversely affecting the dry matter intake and rumen fermentation. Processing of grain to enhance the amounts of rumen resistant starch in ruminants is becoming increasingly important because this type of starch has health enhancing properties like lowering the risk of metabolic disorders, promoting digestion and enhancing the net glucose supply for the host. Further research necessary to find out the supplemental effect of the bypass nutrients on different phases of productive levels and stages need to be investigated in detail.

References

1. Abdel-Ghani AA, Solouma GMA, Abd Elmoty AKI, Kassab AY, Soliman EB. Productive performance and blood metabolıtes as affected by protected protein in sheep. Open Journal of Animal Sciences. 2008; 1(2):24-32
2. Anonymous. Protected proteins for ruminants. All about Feeds, 2019. https://www.allaboutfeed.net/Feed-Additives/ Protected-proteins-for-ruminants-398267E.
3. Bugalia HL, Chaudhary JL. Effect of feeding different levels of formaldehyde treated sesame cake on nutrients intake, milk production and economic returns in lactating crossbred cows Indian Journal of Animal Sciences. 2010; 80(2):152-155.
4. Chalupa W, Vecchiarelli B, Elser AE, Kronfeld DS, Sklan D, Palmquist DL. Ruminal fermentation *in vivo* as influenced by long chain fatty acids. Journal of Dairy Science. 1998; 69:1293-1301.
5. Chatterjee A, Walli TK. Effect of feeding formaldehyde treated mustard cake on growth performance of Murrah buffalo calves, 2003.
6. Chaturedi OH, Walli TK. Effect of feeding graded levels of undegraded dietary protein on voluntary intake, milk production and economic returns in early lactation crossbred cows. Asian Aust. J Anim. Sci. 2002; 14:1118-1124.
7. Chouinard PY, Girard V, Brisson GJ. Lactational response of cows to different concentrations of calcium salts of canola oil fatty acids with or without biocar bonates. Journal of Dairy Science. 1997; 80:1185-1193.
8. Chouinard PY, Girard V, Brisson GJ. Fatty acid profile and physical properties of milk fat from cows fed calcium

salts of fatty acids with varying unsaturation. Journal of Dairy Science. 1998; 81:471-81.
9. Dehghan Banadaky M, Corbett R, Oba M. Effects of barley grain processing on productivity of cattle. Anim. Feed Sci. Technol. 2007; 137:1-24.
10. DePeters EJ, Cant JP. Nutritional factors influencing the nitrogen composition of bovine milk: A review. Journal of Dairy Science. 1992; 75:2043-2070.
11. Devendra C, Lewis D. The interactions between dietary lipids and fibre in sheep. Animal. 2005; 23(23):56-61.
12. Drackley JK. Biology of dairy cows during the transition period; the final frontier. Journal of Dairy Science. 2009; 82:2259-2273.
13. Ekeren PA, Smith DR, Lunt DK, Smith SB. Ruminal biohydrogenation of fatty acids from high oleate sunflower seeds. Journal of Animal Sciences. 1992; 70:2574-2580.
14. FAO. FAO's role in animal production, http://www.fao.org/animal-production/enfusion method. Animal Nutrition and Feed Technology. 2019; 7:95-101.
15. Ganai AM, Sharma T. Performance of lambs fed formaldehyde treated mustard oil cake and bakery waste based concentrate mixture. Animal Nutrition and Feed Technology. 2008; (8):203-212.
16. Garg MR, Mehta AK. Effect of feeding bypass fat on feed intake, milk production and body condition of Holstein Friesian cows. Indian Journal of Animal Nutrition. 2003; 15:242-245.
17. Gowda NKS, Manegar A, Raghavendra A, Verma S, Maya G, Pal DT, *et al*. Effect of protected fat supplementation to high yielding dairy cows in field condition. Animal Nutrition and Feed Technology. 2013; 13:125-130.
18. Hatfield EE. Treating proteins with tannins and aldehydes. in effect of processing on the nutritive value of feeds. Nat. Acad. Sci., Washington DC, 2007, 171
19. Iqbal S, Terrill SJ, Zebeli Q, Mazzolari A, Dunn SM, Yang WZ, *et al*. Treating barley grain with lactic acid and heat prevented sub acuteruminal acidosis and increased milk fat content in dairy cows. Anim. Feed Sci. Technol. 2012; 172:141-149.
20. Jenkins TC. Fatty acid composition of milk from Holstein cows fed oleamide or canola oil. Journal of Dairy Science. 1998; 81:794-800.
21. Khampa S, Wanapat M. Manipulation of rumen fermentation with organic acid supplementation in ruminants raised in the tropics. Pak. J Nutr. 2007; 6:20-27.
22. Leroy JLMR, Opsomer G, Van Soom A, Goovaerts IGF, Bols PEJ. Reduced fertility in high yielding dairy cows: Are the oocyte and embryo in danger? Part II: Mechanisms linking nutrition and reduced oocyte and embryo quality in high yielding cows. Reprod. Dom. Anim. 2008; 43:623-632.
23. Lundy FP, Block E, Bridges WCJr, Bertrand JA, Jenkins TC. Ruminal biohydrogenation in Holstein cows fed soybean fatty acids as amides or calcium salts. Journal of Dairy Science. 2004; 87:1038-1046.
24. Martínez TF, Moyano FJ, Díaz M, Barroso FG, Alarcón FJ. Use of tannic acid to protect barley meal against ruminal degradation. J Sci. Food Agric. 2005; 85:1371-1378.
25. Martínez XP, Sánchez MR, López J, Manjarrez EVA, Padilla EG, Ávila HRV. Desarrollo folicular y tasa Ovulatoria en Cabras Criollas Después de un period corto de Consumo de Trigo Protegido de la degradaciónruminal (Follicular development and ovulation rate in Creole goats after short term consumption of wheat protected from ruminal degradation). Tec. Pecu. Mex. 2008; 46:449-462.
26. Medhi D, Ganai AM, Ahmed HA, Yasir Afzal. Effect of inclusion of formaldehyde treated mustard oil cake in diets on performance of corriedale lambs. Indian J. Anim. Nutr. Microbiological and nutritional outlook. J. Dairy Sci. 90, E17–E38. 2014; 31(3):239-244.
27. Mudgal V, Baghel RPS, Ganie A, Srivastava S. Effect of feeding bypass fat on intake and production performance of lactating crossbred cows. Indian Journal of Animal Research. 2012; 46:103-104.
28. Nagaraja TG, Titgemeyer EC. Ruminal acidosis in beef cattle: The current, 2007.
29. Naik PK, Saijpaul S, Rani, Neelam. Preparation of rumen protected fat and its effect on nutrient utilization in buffaloes. Indian Journal of Animal Nutrition. 2007; 24:212-215.
30. Naik PK, Saijpaul S, Rani Neelam. Evaluation of rumen protected fat prepared by, 2007a.
31. Nocek JE. Bovine acidosis implications on laminitis. J Dairy Sci. 1997; 80:1005-1028.
32. NRC. Nutrient Requirements for Dairy Cattle, 7th rev. ed. National Academy of Sciences, Washington, DC, 2001.
33. Offner A, Bach A, Sauvant D. Quantitative review of *in situ* starch degradation in the rumen. Anim. Feed Sci. Technol. 2003; 106:81-93
34. Orskov ER, Benzie D. Studies on esophageal groove to prevent the fermentation of food in the rumen. British Journal of Nutrition. 2001; 23:415-420.
35. Palmquist DL. Influence of source and amount of dietary fat on digestibility in lactating cows. Journal of Dairy Science. 2007; 74:1354-1360.
36. Patel VR, Gupta RS, Jani VR. Effect of Feeding Bypass Protein on Growth, Body Measurements and Nutrient Utilization in Growing Buffalo Heifers: A Field Trial. Indian Journal of Animal Nutrition. 2012; 29(2):152-156
37. Ramchandran KS, Sampath KT. Influence of two levels of rumen degradable protein on milk production performance of lactating cows maintained on paddy straw based ration. Indian J Anim. Nutr. 1995; 12:1-6.
38. Rhee SJ, Lee JE, Lee CH. Importance of lactic acid bacteria in Asian fermented foods. Microb. Cell Fact. 2011; 10:S5:1-S5:13
39. Sahoo B, Walli TK. Nutrient utilization and growth performance of crossbred goats fed on low and high bypass protein supplemented with molasses as energy source. Abstrac. Proceedings of X Animal Nutrition Conference, Karnal, India, 2001, 132.
40. Saijpaul S, Naik PK, Rani, Neelam. Effects of rumen protected fat on *in vitro* dry matter degradability of dairy rations. Indian Journal of Animal Sciences. 2010; 80:993-997.
41. Sampath KT, Prasad CS, Ramachandra KS, Sudershan K, Subbarao A. Effect of feeding undegraded dietary protein n milk production of crossbred cows. Indian J. Anim. Sci. 1997; 6:706-708.
42. Schauff DJ, Clark JH. Effects of feeding diets containing calcium salts of long chain fatty acids to lactating dairy cows. Journal of Dairy Science. 1992; 75:2990-3002.
43. Schauff DJ, Clark JH. Effects of feeding diets containing

calcium salts of long chain fatty acids to lactating dairy cows. Journal of Dairy Science. 1992; 75:2990-3002.
44. Schmidt J, Toth T, Fabian J. Rumen fermentation and starch degradation by Holstein steers fed sodium hydroxide or formaldehyde treated wheat. Acta Vet. Hung. 54,201–212.hydroxide treatment of barley on digestion in lactating cows. J Dairy Sci. 2006; 78:1106-1115.
45. Sengar SS, Mudgal VD. Effect of feeding treated and untreated proteins on the growth rate pattern and nutrients utilization in kids. Indian J Anim Sci. 1992; 52:51-523.
46. Sharma K. IAI Vision 2020 (Draft document on Vision 2020 for Indian Dairy Industry). In: Proceedings of 1st International Symposium on Future of Indian Dairy Industry, Dec. 1-2, 2011, Karnal, India, 2011, 1-20.
47. Shelke SK, Thakur SS, Amrutkar SA. Effect of feeding protected fat and proteins on milk production, composition and nutrient utilization in Murah buffaloes (Bubalusbubalis). Anim. Feed Sci. Technol. 2012; 171:98-107.
48. Shelke SK, Thakur SS, Shete SM. Productive and reproductive performance of Murrah buffaloes (*Bubalus bubalis*) supplemented with rumen protected fat and protein. Indian Journal of Animal Nutrition. 2012; 29:317-323.
49. Sirohi *et al*., Protection of proteins and fats. Animal feed technology. 2005, 215-225
50. Sirohi SK, Wali TK, Mohanta R. Supplementation effect of bypass fat on production performance of lactating crossbred cow. Indian Journal of Animal Sciences. 2010. 80:733-736.
51. Sklan D, Kaim M, Moallam U, Folman Y. Effect of dietary calcium soaps on milk yield, body weight, reproductive hormones, and fertility in first parity and older cows. Journal of Dairy Science. 1994; 77:1652-1660.
52. Sukhija PS, Palmquist DL. Dissociation of calcium salts of long chain fatty acids in rumen fluid. Journal of Dairy Science. 2002; 73:1784-1787.
53. Sutton JD, Knight R, Mc Allan AB, Smith RH. Digestion and synthesis in the rumen of sheep given diets supplemented with free and protected oils. British Journal of Nutrition. 2000; 49:419-432.
54. Thakur SS, Shelke SK. Effect of supplementing bypass fat prepared from soybean acid oil on milk yield and nutrient utilization in Murrahbuffaloes. Indian Journal of Animal Sciences. 2010; 80:354-357.
55. Tyagi N, Thakur SS, Shelke SK. Effect of feeding bypass fat supplement on milk yield, its composition and nutrient utilization in crossbred cows. Indian Journal of Animal Nutrition. 2009; 26:1-8.
56. Wadhwa M, Grewal RS, Bakshi MPS, Brar PS. Effect of supplementing bypass fat on the performance of high yielding crossbred cows. Indian Journal of Animal Sciences. 2012; 82:200-203.
57. Walli TK, Sirohi SK. Evaluation of heat treated soybean on lactating crossbred cows. Project Report of the Collaborative Project between National Dairy Research Institute, Karnal and American Soybean Association, New Delhi, 2004.
58. Yadav CM, Chaudhary JL. Effect of feeding protected protein on nutrient utilization, milk yield and milk composition of lactating crossbred cows. Indian J Dairy Sci. 2010; 57:394-399.
59. Yu J, Wang WH, Menghe BLG, Jiri MT, Wang HM, Liu WJ, *et al*. Diversity of lactic acid bacteria associated with traditional fermented dairy products in Mongolia. J Dairy Sci. 2011; 94:3229-3241.