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Integration of Forage Sorghum and By-Products of Sugarcane and Sugar Beet Industries for Ruminant Nutrition: A Review

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Abstract: Ruminant nutrition is one of the most important factors which determine their productivity and performance in terms of milk and meat production. In Pakistan, large ruminants are underfed and rations are not balanced on quality scale. Forages are the most palatable animal feed resource along with being economical and provide major chunk of animal feed resource base. Recently among cereal forages, sorghum has gained attention due to its drought and heat endurance characteristics. Forage sorghum was considered to be the crop of rainfed areas in Pakistan, but emerging agricultural water shortage has necessitated its cultivation on large scale in irrigated areas as well. Forage sorghum has higher water use efficiency and its economics of production gives it upper hand over other cereal forages particularly maize. Forage sorghum holds key in bridging the gap between digestible nutrients supply and demand in times to come. Forage sorghum intercropping with forage legumes and its preservation as hay or silage is bound to reduce the drastic effects of forage scarcity during May-June. If by-products of sugarcane and sugar beet industries like molasses, bagasse and filter cake are included in animal feed in addition with sorghum fodder, the productivity of dairy animals can be doubled. However there is a dire need to initiate a breeding program to develop high yielding forage sorghum varieties and an extension program must be launched to make farmers aware of latest production technology of forage sorghum. Last but not least, there is need of hour to develop techniques so that by-products of sugarcane as well sugar beet industries may be utilized for ruminant nutrition and only this type of animal feed resource base diversification can ensure milk production on sustainable basis.

Key words: Animal Nutrition · Cereal Forages · Hay and Silage · Bagasse and Molasses · Press Mud

INTRODUCTION

Large and small ruminants in mixed farming system are the source of additional income for farmers. Mixed farming system which involves rearing of crops and livestock together also provides security in the wake of crops failure. Subsistence mixed farming is quite common and being practiced by small land holders on large scale in Asia particularly in Indo-Pak subcontinent and many African countries [1]. Pakistan owns precious breeds of cattle and buffalo and because of their higher potential for milk, Pakistan has occupied third slot among largest milk producing countries in world. Despite the fact that Pakistan was able to produce about 51 million tons of milk in 2013 [2], but it is a matter of great concern that productivity and performance of milch animals in Pakistan is much low in comparison with their known potential. There are many reasons which have been assigned for poor performance of milch animals, but under-nourishment is the leading cause [3-5]. Ruminants are provided with different feed stuffs like forages, fodders preserved as hay and silage and crop residues along with protein and energy rich concentrates [6-11]. But still ruminant are confronting a severe shortage of total

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digestible nutrients (TDN) in the range of 29-31% and crude protein deficiency stands at 33% [12]. It clearly indicates that ruminants are not being provided with required quantities of digestible nutrients as well as crude protein, while the number of animals is increasing with each passing year. Forages which are most palatable and economical feed resource become deficient during months of extreme heat and cold in Pakistan [13-16]. During these periods of forage scarcity, milk production takes a nose dive as animals remain under-nourished. Furthermore, changing climate and emerging agricultural water shortage have made the situation from bad to worse [17, 18]. Forage sorghum has been recognized to be one of the most heat and drought resistant cereal forage [19]. Though sorghum is considered to be the crop of rainfed areas but now it has been gaining popularity among dairy farmers of irrigated tracts of Pakistan. Despite the fact that forage sorghum has the potential to give fairly high forage yield, but it is also poor in terms of crude protein content [20-22]. Thus there is a dire need to integrate other alternate sources of protein and digestible nutrients that may be fed along with forage sorghum during lean periods. For this, a variety of byproducts produced by sugarcane and sugar beet industry have the potential to bridge the gap between digestible nutrients supply and demand.

This review study provides a candid analysis of forage sorghum suitability for irrigated tracts of Pakistan, particularly of Punjab to supply green forage in sufficient quantities during forage scarcity periods. This review study also comprehends the potential use of different byproducts of sugarcane and sugar beet industry as animal feed resource to increase the milk productivity of animals.

Credentials of Forage Sorghum and its Suitability as a Forage Crop for Irrigated Tracts: Forage sorghum is one of the most heat and drought resistant members of poaceae family. It has the potential to sustain moderate intervals of drought because of a variety of physiological and morphological adaptations [23]. As climate change and global warming have become more pronounced in last decade and have brought into light the potential of sorghum to be a C4 crop. Though maize is also a C4 crop, but it is sensitive to drought and heat in contrast to sorghum [24]. Sorghum survives extreme heat periods by reducing transpiration and this is achieved by rolling its leaf and due to the presence of layer of thick cuticle on the leaves and its stem which results in a significant reduction of transpiration rate [25]. Sorghum has much higher water use efficiency [26, 27] than any cereal forage which makes it one of the best alternate forage crop for rainfed as well as irrigated tracts of Pakistan. The need of sorghum cultivation in place of forage maize is also supported by the fact that Pakistan is facing a severe shortage of agricultural water and present water scenario is predicted to become even more serious in times to come. Sorghum also holds advantage in terms of cost of production when compared with other cereal forages due to cheaper seed rate, fewer requirements of irrigation and fertilizers and potential to sustain periods of extreme heat and moderate drought without significant losses in green forage yield. Forage sorghum has 33-35% dry matter (DM), 7-8.5% crude protein (CP), 1.5-2% ether extract (EE), 31-33% crude fiber (CF) and 53-54% nitrogen free extracts (NFE) [23]. It has the potential to give green forage yield in the range of 60-80 tons per hectare if proper agronomic principles and practices are to be followed [28, 29, 30]. Forage sorghum was considered to be the crop of rainfed areas of Punjab, but now it is gaining popularity in irrigated tracts of Punjab and Sindh. Forage sorghum was cultivated on an area of 6 million hectares with production of 8 million tons in Punjab province in 2013 (Fig. 1). But it is a matter of grave concern that the per hectare forage yield of sorghum (13-13.5 t ha^{-1}) is much less than the potential of this crop [31, 23]. This may be for many reasons such as poor and inappropriate seed bed preparation, seed of low yield potential, suboptimal plant population, no irrigation at proper time and in required quantities, fewer and imbalanced use of fertilizers, ignored insect-pest management and last but not least is the inappropriate time of harvesting [32]. All these factors have reduced forage sorghum yield to 13 t ha^{-1} instead of 50 t ha^{-1} (Fig. 2). Farmers are using traditional crop production practices with giving due attention to latest and modern production technology. The need of hour is to launch a dedicated and rigorous extension program by provincial agriculture and livestock departments to make farmers aware of suitability and advantages associated with forage sorghum cultivation to increase the acreage under forage sorghum. Furthermore, farmers and other personnel related to dairy industry must be made aware of latest production technology in order to give upward lift to forage sorghum production. As the number of milch animals in Pakistan is increasing rapidly [2, 34] and these constitute the finest breeds of cattle and buffalo, so proper animal nutrition management has the potential to bring a white revolution in Pakistan by doubling milk production and in this context, forage sorghum has an important role to play in coming times.

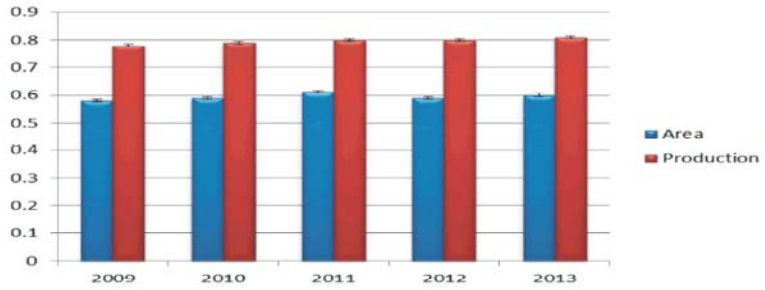

Fig. 1: Area (million hectares) and production (million tons) of forage sorghum in Punjab [33].

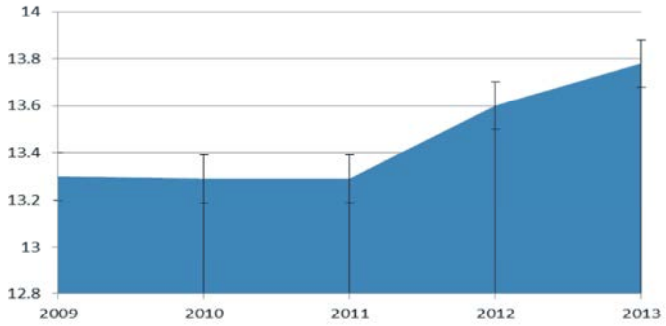

Fig. 2: Forage sorghum yield (tons per hectare) in Punjab [33].

Boosting Mixed Forage Yield and Quality with Sorghum-Legumes Intercropping Systems: Forage sorghum holds bright future as an alternate forage crop for irrigated tracts as well as rainfed areas due to its drought and heat enduring characteristics and economical production [23]. But the fact of matter is that forage sorghum is poor on nutritious scale as compared to crops like barseem, shaftal and other forage legumes [23]. Thus forage sorghum intercropping with forage legumes such as cowpea, cluster bean, soybean etc. has the potential to increase the production as well quality attributes of mixed forage. Intercropping is the practice in which different crops are sown at the same time in same field. Forage sorghum may be intercropped with cowpea cluster bean or soybean in row intercropping or mixed intercropping [35, 36]. In row intercropping there are distinct rows of forage sorghum as well as of intercrops, while in mixed intercropping, there is no row distinction rather blended seeds of sorghum and legumes are sown in the same line. The mixed forage yield increases with intercropping of forage sorghum and legumes due to better land equivalent ratio [37-39]. Higher mixed forage yield is also attributed to better use of soil and environmental resources due to different consumption patterns of different crops [40]. Cereal-legume based intercropping systems are also beneficial as leguminous crops are known to restore soil fertility status which is the inherited capacity of soil to provide essential plant nutrients in sufficient quantities [41]. The quality of mixed forage gets improved when forage sorghum is intercropped with legumes as legumes especially protein contents are increased due to higher protein percentage contributed by leguminous crops. Forage sorghum contains only 7-8.5% protein [23], while forage legumes such as cowpea, cluster bean and especially soybean contain protein in double figure than forage sorghum. Furthermore, these forage legumes are totally compatible with forage sorghum in terms of sowing time and irrigation requirement. Cowpea and cluster bean are especially shade resistant crops and their green forage yield does not get reduced due to the shading effects caused by longer forage sorghum plants [40]. Three or four irrigations depending upon the climatic conditions are enough for the entire growing period of sorghum as well as forage legumes such as soybean, cowpea and cluster bean [39]. It should be noted that legumes are nitrogen savers not the contributors and increase soil fertility by fulfilling their nitrogen requirement through the process of symbiotic nitrogen fixation which takes place in the nodules which are present on roots of legumes. Thus intercropping of forage sorghum with forage legumes constitutes a viable option for rainfed as well as irrigated tracts to increase the green forage yield as well as to improve the quality attributes of mixed forage along with increasing the soil fertility status of the soil.

Sorghum Preservation as Hay and Silage: There are two periods (May-June and November-December) in each year during which forages are not there in sufficient quantities to meet the requirement of dairy animals [42] and resultantly milk production takes a hectic nose dive in Pakistan. During forage scarcity periods, not only animal health suffers a serious setback, but a greater proportion of farmer's income is sliced due to reduced milk production. Keeping in view the skyrocketing population of Pakistan and huge foreign exchange reserves being spent in importing dairy products, there is a need of efforts to reduce the drastic effects of forage scarcity periods. One reasonable option to achieve this goal may be the preservation of forage sorghum as hay and silage to feed animals on them during lean periods. Hay is the air dried fodder which is prepared by placing green succulent forage under shade in order to reduce the moisture contents [43]. As the moisture contents are reduced in shade drying and ultimately shelf life of fodder increases and these may fed to dairy animals during forage scarcity periods. Sorghum hay preparation is not a difficult task and farmers can prepare it after getting some basic knowledge of hay making and constructing basic infrastructure. As forage sorghum is summer season forage, so it has the potential to neutralize the ill-effects inflicted by forage scarcity during lean period of May-June, if excess quantities of green forage are to be preserved as hay by farmers. It is without any shadow of doubt that forage preservation as hay and silage is one the finest inventions in the field of ruminant nutrition and dairy industry [44]. But the farmers in Indo-Pak subcontinent and other African countries have failed to take benefit of this forage preservation technique and ultimately suffer on an individual and country scale. Forage sorghum if preserved as hay may not only improve the milk production but also gives a boost to animal health and that too in an economic way as farmers do not require complex infrastructure or technical know-how. The climate of Indo-Pak subcontinent and Africa is excellent for hay making as there are no frequent and torrential rains and plenty of sunshine is available. So carefully prepared sorghum hay without leaf shattering and leaching of nutrient is one of the most viable option for dairy farmers to use it during months of extreme heat. Similarly silage making is another ground breaking forage preservation technique which can provide excellent nutrition to large and small ruminants. Silage is the fermented fodder that is prepared in specially built structures called silos in air tight conditions with the addition of molasses, urea and other additives in anaerobic conditions [19]. Sorghum silage prepared in an appropriate way provides good quality of animal feed and that too for a longer period of time. Sorghum has all credentials that a crop must have in order to be ensiled to prepare silage. Though silage preparation is more technical and expertise requiring technique of forage preservation than hay making, but it is a matter of great interest sorghum silage is more nutritious and various researchers have found sorghum silage a better tonic than hay as far as animal nutrition is concerned. Sorghum silage hold more advantages than maize silage as sorghum production is much economical than maize. Sorghum requires fewer nutrients and irrigations and gives fairly high yield of green succulent forage in comparatively less time span with higher water use efficiency (WUE) and fertilizers use efficiency (FUE) [19, 23]. It is a matter of great regret and remorse that dairy farmers in developing countries like Pakistan, India and other African countries continue to remain ignorant of these unprecedented forage preservation techniques that have the potential to bring white revolution in these countries by doubling milk production and improving animal health and productivity. So there is a dire need to make farmers aware of these techniques and subsequently training them along with providing soft loans to build necessary infrastructure.

Potential of Sugarcane and Sugar Beet Industries By-Products for Ruminant's Nutrition: By increasing acreage under forage sorghum, it's intercropping with forage legumes such as cowpea, cluster bean, soybean etc. and sorghum fodder preservation as hay or silage has the potential to bridge the gap between digestible nutrients supply and demand. But matter of fact is that there is a dire need to diversify the sources for digestible nutrients as well as protein for sustainable milk and meat production. In this context, a variety of by-products produced by sugarcane and sugar beet industries may find their use in addition with forage sorghum to fulfill the nutritional needs of ruminants during periods of forage scarcity. Pakistan is 9th biggest sugarcane producing country among 90 sugarcane producing countries of the world with total cane production of 65 million tons and area under this crop is usually 1.1 million hectares with average cane yield of 66 tons per hectare [45-48]. Sugarcane industry is the second largest agro-based industry of Pakistan after textile industry. There are about 86 sugar mills in Pakistan and most of them are situated in Punjab and Sindh provinces [45]. Similarly, sugar beet is another sugar crop mostly being grown in KPK province

of Pakistan and on a limited scale in Sindh province with average yield of 22-40 tons per hectare which is much below than its potential [49, 50]. There are only two fully functional sugar beet mills in KPK. However a large number of by-products are being produced by these sugarcane and sugar beet mills in addition with sugar production. These by-products have a bright future to be utilized for ruminant nutrition not only in Pakistan but all other countries having sugarcane or sugar beet mills.

Bagasse from Sugarcane Industry: Bagasse is the fibrous left overs of sugarcane when it is crushed in machines in order to extract the cane juice for sugar preparation [51]. Hundreds of thousand tons of bagasse are produced during crushing season of sugarcane as about 3 tons of wet bagasse is produced by sugar mills after crushing 10 tons of sugarcane [52]. This huge quantity becomes a mean of headache for sugar mills management because of limited capacity of storage particularly if there are no biofuel, pulp and various types of building materials preparing industries. It is a matter of interest that only a small fraction of bagasse is burnt during the cycle of production of sugar. Due to its bulkiness, it is expensive to transport bagasse to other areas for consumption or dumping. In past, some sugar mills used to burry deep this bagasse in order to clear their stores for more sugarcane storage. But with passage of time the importance of bagasse has come to light after recognizing the importance of fibrous feeds for large ruminants. Typically bagasse contains cellulose 45-55%, hemicellulose 20–25%, lignin18-24%, ash1-4% and waxes less than 1%, while the crude protein contents are only in the range of 1-1.3% [53]. It is interesting to note that a group of industries with the name of K-Much invested heavily on research and development of means for conversion of bagasse into appropriate animal feed. After years of research, they have converted bagasse into a fiber rich animal feed after treating bagasse with molasses in anaerobic conditions which is now being sold in Australia, Taiwan, Korea, Japan, Malaysia and Thailand [54]. The biggest hurdle in the way of bagasse utilization as animal feed is its low digestibility which is in the range of 45-50% mainly because of presence of higher cellulose-lignin contents [55]. The digestibility of bagasse may be increased by fermenting it with molasses, but the real issue is economics as bagasse fermentation becomes quite expensive due the use of specific chemicals. However, researchers have found certain yeast effective in fermenting bagasse with molasses which increases the digestibility of bagasse to a reasonable extent. In another research it was found that when bagasse was treated with molasses, urea and common salt and stored in anaerobic conditions, the resultant silage of bagasse was of fairly high quality. Bagasse are crushed and treated with molasses in the presence of hot steam and pressure and fed to animals in some countries like Brazil [52]. Thus with the development of modern physical, chemical and biological methods and protocols to increase the digestibility of bagasse, it holds a bright scenario to be utilized as animal feed with reasonably higher digestibility in times to come.

Molasses from Sugarcane and Sugar Beet Industries: The word molasses was derived from Latin word *mel* which means honey. It is a by-product of sugarcane and sugar beet industry produced during processing and is vicious in nature [56]. Chemically sugarcane molasses contain no crude protein, crude fiber or fat. It contains carbohydrates (Sucrose, glucose and fructose) and many minerals such as calcium, magnesium and iron [57]. Sugar beet molasses are different from sugarcane molasses chemically as it contains 50% sugar (predominately sucrose) and minerals constitute calcium, oxalate, chlorine and potassium [58]. Molasses may be given to small and large ruminants freely for licking. Molasses may be fed to animals but only to permitted range of 5-10% in combined feed [56]. It also finds its use to increase the palatability of cereal straws such as of rice straw to be fed to animals during forage scarcity periods. Molasses are also added to silage of different cereals in order to increase the palatability and same is the case with hay. Pakistan produces a huge quantity of molasses during processing of sugar in sugarcane and sugar beet industries as much as 2.1 million tons in 2013 (Fig. 2) [59]. This huge quantity of molasses may be made available to farmers in order to use it in silage preparation as well as to improve the digestibility of rice straw for use in November-December and wheat straw use in May-June during which green forage availability is reduced and performance of dairy animals is hit the hardest.

Filter Cake/Press mud: Press mud is the residue which is obtained after the filtration of sugarcane juice. The clarification process separates the juice that goes upward for further processing and mud gets collected at the bottom. This collected mud is then subjected to filtration in order to separate the suspended matter, which usually is comprised of different insoluble salts and fine bagasse.

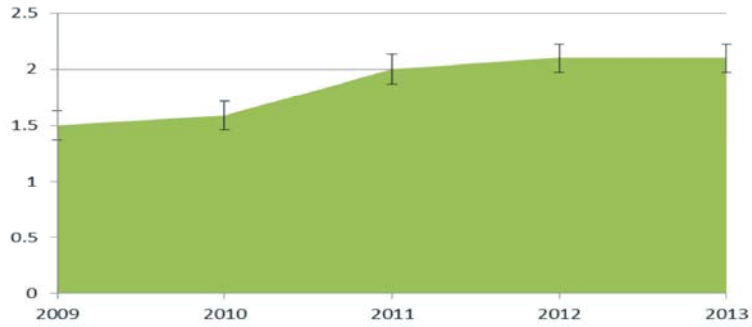

Fig. 2: Molasses production by sugarcane and sugar beet industries in Pakistan [59]

The quantity of press mud or filter cake obtained varies between 1-7 kg per 100 kg of crushed sugarcane depending upon the type of crushing machines and sugarcane age [60]. The crude protein contents of filter cake are in the range of 12-15% depending upon the type of processing and filtration. The digestibility of dry matter contained in filter cake is less than 35%, while that of crude protein is just 20% [61]. It is recommended to sundry filter cake before feeding to ruminants as higher moisture contents decrease the palatability of filter cake to a great extent. It is considered to be a mineral rich feed for ruminants as mineral contents are in the range of 10-30% [62], but some studies have reported the presence of some undesirable elements like copper that may adversely affect small ruminants particularly sheep. However its use as ensiling agent has been found to be secured as well as effective. It is suggested to feed cattle with filter cake up to 15% of dry matter [63]. Huge quantities of filter cake are produced in Pakistan which is considered as waste so there is a dire need to develop protocols in order to bring this by-product in appropriate combinations in rations.

CONCLUSION

Pakistan has been bestowed by nature very rich breeds of cattle and buffalo as far milk production is concerned. But poor animal nutrition management has kept milk production much below considering the potential as well as number of large ruminants in Pakistan. Forages are the most important and economical animal feed resource but their deficiency during extreme hot and cold months hampers milk productivity. Forage sorghum has the potential to bridge the gap between total digestible nutrients supply and demand. Forage yield as well quality attributes of mixed forage are improved in sorghum-legumes intercropping systems. Furthermore, sorghum fodder may be preserved as hay or silage to feed animals during May-June when there is a severe shortage of green forages. There is a dire need to increase area under forage sorghum along with boosting its yield on per hectare basis particularly in irrigated tracts of Punjab province. Animal feed resources are also needed to be diversified at the same time. By-products of sugarcane and sugar beet industries such as bagasse, molasses and filter cake if integrated with forage sorghum can reduce the drastic effects inflicted by green forage shortage. The need of hour is to launch a comprehensive research program in order to improve the palatability and digestibility of different by-products produced by sugarcane and sugar beet industries by developing advanced protocols and techniques. Only diversification of animal feed resources can ensure better productivity of dairy animals to meet the needs of skyrocketing population in times to come.

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