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Overview on Sorghum for Food, Feed, Forage and Fodder: Opportunities and Problems in Pakistan's Perspectives

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Abstract: Sorghum is a member of Poacea family and is considered to be the fifth most important cereal worldwide. It is a multipurpose crop which finds its use in a variety of food and feed products globally. Drought and heat resistant characteristics along with ability to tolerate soil toxicities have made this crop widespread from Africa to Americas to Asia. Sorghum is satisfying dietary needs of millions of people in Africa as it grows well in harsh climatic conditions where other cereals fail to take stand. It finds its use in a variety of beverages and baked products after going through fermentation, malting, baking, popping, roasting, brewing, boiling and milling. In Pakistan, there are no processing units for sorghum grain and farmers have remained ignorant of potential of this crop. As sorghum is being grown in arid, as well as, irrigated tracts of Pakistan, thus government needs to encourage the installation of processing facilities. In this way, farmers will tend to switch to this crop with the creation of market value of sorghum and with the passage of time; general public will also develop taste for sorghum products similar to tea and coffee. Sorghum grain is the best alternate of maize because it is almost equivalent to maize on nutrition scale. Sorghum requires fewer inputs and yields more, thus it has a bright future as far as poultry and animal feed is concerned. Forage sorghum cultivated in intercropping systems with legumes provides nutritious forage to dairy animals and that too much economically due to less use of irrigation and fertilizers. Sorghum fodder may also be preserved as hay or silage to feed animals during green forage shortage periods. Thus the need of hour is to exploit full potential of this crop to ensure sustainable animal feed supply and ultimately human food security.

Key words: Cereals · Drought · Jawar · Hay and Silage · Food Security

INTRDUCTION

Sorghum (*Sorghum bicolor* L.) is known as Jawar in Indo-Pak subcontinent, durra and kaffir corn in Africa and kaoliang in China. It belongs to *Poacea* family and *Andropogonae* tribe [1]. It is a close relative of sugarcane. Sorghum name was derived from Italian word *Sorgo* which in turn was derived from Latin word Syricum meaning grain of Syria. Sorghum name was suggested by Person who named it as *Sorghum bicolor* (L.) Moench [2]. It is considered to be the fifth most important crop after rice, wheat, maize and barley worldwide. It is a multipurpose annual summer cereal which is satisfying diverse human needs since immemorial times. It is believed to be originated in Ethiopia from wild sorghum about 5000 years ago, from where it spread to other parts of world [3]. Now it accounts for more than 43% of cultivated cereals in Africa. It was introduced in Indo-Pak subcontinent during the arena of about 100 B.C. It has been successfully grown in tropical and subtropical regions on a wide scale. Nigeria, USA and Indo-Pak regions are ranked as the top producers of sorghum in the world. USA and Australia were the top exporters of sorghum, while Mexico was the leading importer during 2012-13 [4]. It is a heat resistant crop and can tolerate a fairly high range of temperatures without compromising the economic yield [5]. Furthermore, its ability to tolerate soil toxicities has made this crop successful on a variety of soils from Africa to Asia to Americas [6]. Being a C4 crop, it grows well in hot dry areas world especially in central Africa. Sorghum can tolerate drought due to its high root to leaf ratio and ability to become

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dormant. Reduced transpiration rate due to the presence of thick waxy cuticle on leaves and rolling of leaves in the wake of moderate to severe drought [7, 8] is another important factor which makes sorghum excellent choice for drought prone areas. It has a wide adaptability to soil types from deep sandy soils to black cracking clay soils. Sorghum has the potential to tolerate moderate levels of salinity levels and may be grown on all types of salt-affected soils such as saline soils, sodic soils and saline-sodic soils [9]. Sorghum finds its use in a variety of food and feed products. It continues to remain the staple food of millions of people in third world countries where it has been grown on fewer inputs of water and fertilizers [10]. Sorghum has the potential to produce a fairly high grain and forage yield with fewer use of inputs if good crop husbandry is to be followed. The emerging global warming scenario has made sorghum a good potential cereal crop to be used by human beings. The skyrocketing population and scarcity of agricultural water [11] with each passing year has necessitated the inclusion of drought and heat resistant crops in cropping pattern. But it is a matter of grave concern that this crop continues to remain underutilized despite numerous benefits and advantages [12]. As sorghum is dubbed as coarse grain cereal and poor man's food, it needs to be included in modern food commercialization system. There is dire need to make investment on research and development of sorghum along with its value addition in order to secure the food security of teeming millions. It is a high time to include this crop into the food basket of masses keeping in view the changing environmental quality and its adverse effects on traditional crop production systems.

The aims and objectives of this article are to illustrate sorghum grain and green forage yield potential along with grain and forage quality attributes; to highlight the value addition and processing technologies, alternate food products that may be prepared from sorghum and last but not least to bring into light the constraints and opportunities for production as well as commercialization of sorghum in rainfed and irrigated tracts of Pakistan.

Sorghum Grain Utilization in Food Products: Sorghum grain fulfill the dietary needs of millions of people in Africa and other developed countries like USA, Brazil and Mexico, but it continues to remain underutilized in Asia and particularly in Indo-Pak subcontinent. The per capita consumption of sorghum is only around 2.3 kg per person per year against the value of 174 kg person^{-1} year^{-1} of other cereals in Indo-Pak subcontinent [13]. However in some areas of Pakistan and India where extreme poverty prevails, coarse grains constitute 20% of total cereal intake, while in some Indian states, this figure falls in the range of 45-50% [14]. Sorghum grain is considered to be the most amenable cereal which may be utilized after subjecting it to different levels of processing such as primary (popping, roasting, fermentation, boiling and milling), secondary (baking, brewing, steaming and beverages preparation) and tertiary (making composite flour of sorghum with other cereals and legumes as well as fortification with natural and artificial additives) processing [15]. Sorghum grain may be used traditionally to prepare food for domestic needs as well as for industrial use. Sorghum has been recognized to have a considerable potential to be used in a variety of products for human food along with numerous beverages. In advanced countries, locally grown sorghum is commercially processed into value-added food and beverage products [16] which constitute as an important driver for economic and social development of these countries. The use of sorghum in food and beverage industries provides farmers with a market but also reduces precious foreign exchange, which would otherwise be required to import cereals like wheat, maize and barley. Sorghum is used in many countries like Sudan and India as a whole grain quite similar to rice [17]. It has been suggested that use of sorghum as a whole grain is much easier than rice because only outer layer bran layer is needed to be removed from boiling the grain [18]. It is matter of intense interest that a growing demand for non-traditional food products such as gluten-free foods and beverages has been witnessed from people who are suffering with coeliac disease which causes intolerance to wheat and barley due to indigestion of wheat protein caused by damaged mucosa [19]. The antioxidant presence ranks sorghum flour higher on health scale. Sorghum wax which is produced on pericarp surface of sorghum grain holds numerous health related advantages due to the presence of long chain lipids. These lipids reduce the concentration low density lipids in blood and bring down the cholesterol level. Sorghum gluten free bread has the potential to replace wheat bread for coeliac and heart patients. Sorghum bread was recognized as an alternate crop of wheat in developing countries many decades ago. It was suggested that if xanthan gum is added to sorghum flour, it develops all characteristics of wheat flour [20-23]. One of the concerns regarding sorghum flour was the presence of tannins in the testa of sorghum kernel. But researches have explored that presence of tannin ensure safe storage of sorghum by

preventing them against the invasion of insects, birds as well as other pathogens. Furthermore, if sorghum kernels are treated with very dilute formaldehyde, tannins are rendered inactivated making their use more secure in brewing and malting [24]. In Pakistan, though beer industry cannot be established on religious grounds but use of sorghum flour in baking products like cakes, porridges, cookies, snacks and pasta holds a bright potential. Sorghum has the potential to give better brewing as well as malting properties than barley, provided appropriate extraction procedures and techniques are to be followed. In Pakistan, as the climatic conditions are excellent for sorghum production and emerging water scenario has necessitated the production of sorghum on wide scale and subsequently using it in beverage and food industry for local needs as well as for exports. This crop holds immense potential for food and beverage industries only if its potential gets realized on government and public level. Though, there are not much sorghum grain processing plants in Pakistan, but if Government provides subsidy on the imports of technological equipment and processing unit, then a full-fledge sorghum-fed food industry can set foot. This industry holds immense potential to offer employment to hundreds of thousand people and this scope even become brighter in the face of foreign investment in sorghum production as well as utilization sectors. The first and foremost thing that is the need of hour is the realization of sorghum potential in beverage and food market. For this a comprehensive extension campaign must be launched to make farmers aware of the potential of this drought and heat resistant crop. Despite a variety of potential uses and available processing technologies, unfortunately sorghum has not find its fair use in food market of Pakistan. Sorghum has not been used in beverage and baking food industry in Pakistan due to a variety of factors including lack of awareness and taste. Wheat being the staple food for Pakistanis has made it difficult for sorghum to enter into food market. There are problems on both production as well as utilization side. Farmers tend to grow only those crops which are in demand and give then fair returns. If any crop which has no or little market value will never grab the attention of farmers because in agriculture everything revolves around economics. So up till now dilemma persists that whether processing industries and units need to be made functional first or growers must be persuaded to opt for sorghum crop as an alternate crop. The matter of fact is that sorghum is being grown in Punjab's rainfed as well as irrigated tracts, so need of hour is to install processing units of baking products and beverages and in this way farmers will be attracted towards this crop and the area under sorghum may be multiplied within no time. This is because of the reason that if market value of sorghum gets created, it will act as self-promotion and advertisement and little effort would be required to make growers aware of importance associated with this crop. Once sorghum grain will find its use in baking products and beverages, people will develop taste with the passage of time. If history is any witness, the case of tea, coffee and other similar products is the proof which got acceptance among general masses with passage of time, despite initial social dogma and food preferences. Thus government needs to subsidize imports of sorghum grain processing units on one side and on the hand it needs to provide funds for developing hybridized sorghum of food grade. Thus sorghum as a cereal crop holds very bright potential in Pakistani perspectives, but the need of hour is develop food grade sorghum cultivars and process it for a variety of food and beverage products. Sorghum based food may be used to fulfill local dietary needs such as to provide nutritious food to Thar people suffering from starvation on massive scale. Though it is an uphill task, but food security can only be ensured by diversifying food resources and skyrocketing population in Pakistan has further aggravated the necessity to make sincere and tireless efforts in this context.

Suitability and Consumption of Sorghum Grain as a Feed Resource Base for Ruminant Production: In last two decades or so, the area under sorghum crop has increased by more than 60%, while it is interesting to note that its yield has taken a sharp jump so much so that it has increased by 233% in comparison with two decades ago worldwide [25]. In Pakistan, area under sorghum has increased rapidly but the yield has not been increased due to a variety of limited factors. Sorghum grain is primarily poultry feed [10] and a secondary animal feed in Pakistan. Sorghum is considered to be the best alternate of maize for poultry and animal feed when and nutrition and other variable economic aspects are taken into consideration. The kernel of sorghum is much similar to maize grain as far nutrition is concerned despite the fact that sorghum kernel is much smaller in size than that of maize grain [26, 27]. The nutritional value of sorghum grain to be fed to animals varies depending upon many factors such as variety, climatic conditions, soil type, as well as, type and quantity of fertilizers applied [28, 29, 30]. All these factors

mainly determine the chemical composition, as well as, anti-nutritional substances like tannin content of sorghum grain [31]. However, it was reported by many animal nutrition specialists that sorghum whole grain is the best alternate of maize as it contains as much as crude protein as that of maize grain [32]. It has also been reported that some sorghum varieties in Nigeria contain protein equal to wheat and higher than maize [33]. Some other studies revealed that sorghum grain is higher in fat contents than wheat but lower than maize [34]. Maize contains more lysine than sorghum but tryptophan contents are higher in sorghum than maize [35, 36]. Another interesting factor which increases the nutrition of sorghum is the presence of yellow endosperm and xanthophylls in sorghum kernels [37]. In Asia, 35% of sorghum grain finds its use as animal feed, while its corresponding figure in Indo-Pak is only 8-10% [3]. It is a matter of interest that 58% of sorghum grain is being utilized as animal feed in China, while the corresponding figure on worldwide sale is more than 51% [3]. In USA too, sorghum is mainly used as an animal feed resource [38] and is considered to be a good and viable alternate of maize. It was reported that sorghum grain is more or less equal to maize on nutrition scale and may be used as an animal feed resource to diversify the animal feed resource base [39]. Due to sorghum grain equality with maize on nutrition scale, it can be fed to all classes of livestock including large and small ruminants, as well as, poultry birds. This argument is further strengthened by researches which demonstrated that feeding value of sorghum is 90-100% to that of maize [40] which makes sorghum a strong candidate to be included in animal feed resource base in countries like Pakistan where it has been ignored as an animal feed despite having excellent climatic and soil conditions for sorghum production. In Pakistan, sorghum in reasonably high quantities gets moved from sorghum producing rainfed areas to urban and peri-urban areas mainly to fulfill poultry and animal feed requirements [41]. Sorghum grain for poultry and animal feed costs 10-15% less in comparison with other cereals like maize and barley [42]. In Pakistan, sorghum grain use as poultry feed followed by dairy feed hold immense potential. But it should be noted that maize is the main competitor of sorghum in Pakistan, thus feed manufacturers would only prefer sorghum over maize if its cost is significantly less as compared to maize. Another problem is that sorghum supply is not sustainable throughout the year unlikely of maize which hampers sorghum preference among poultry and animal feed manufacturers. This situation is like "which come first, chicken or egg?" as in the absence of sufficient market for sorghum grain, growers cannot be convinced to opt for more profitable crop of sorghum in place of maize and on other hand, without sustainable grain supplies, manufacturers and industrialists would not be attracted to incorporate sorghum grain in their production capacity. Farmers do not have storing facilities to store the product and wait for reasonable price and they can ill-afford to keep their produce with them as the farmers are cash starved and need capital to settle previous debts and to purchase farm inputs for next season. Thus there is a dire need to initiate an extension program in arid as well as irrigated tracts of Punjab and Sindh provinces to increase the acreage under this crop. Furthermore, it is interesting to note that sorghum grain has the lowest digestibility among cereals due to the presence of hard endospermic layer. Tannin contents also continue to remain a matter of concern for animal nutritionists. There the need of hour is to launch a comprehensive breeding program to develop sorghum cultivars which are low in tannin contents and have higher digestibility by reducing the hardiness of endospermic layer. If these two objectives are achieved, sorghum grain has the potential to bypass all other cereals on nutrition sale as far as ruminant's nutrition is concerned.

Forage Sorghum for Milch Animals: Sorghum is one of the oldest cultivated green forages for lactating animals. It constitutes excellent green forage for ruminants particularly dairy animals. Its drought and heat resistant qualities along with ability to tolerate soil toxicities [43] has made it a good option for dairy farmers and forage growers particularly in tropics. Climate change and phenomenon of global warming are though raising eyebrows of researchers and agricultural policy makers but being a C4 crop, sorghum holds a bright future as production of C4 crops have been predicted to be raised in the face of temperature hikes. Forage sorghum needs little irrigation requirement [44] when compared with maize which makes it a suitable crop for rainfed areas as well as irrigated tracts. As forage sorghum production is much economical due to fewer requirements of irrigations as well as fertilizers and it can yield reasonably high yield even in the face of harsh climatic conditions such as drought and temperature extremes, thus it can go a long way in enhancing milk and meat production in developing countries like Pakistan to support skyrocketing population suffering from malnutrition [45]. In Pakistan, agricultural water availability is continuously on decline

Table 1: Nutritional profile of sorghum and maize grain (%) adapted from Iqbal *et al*. [10].

Quality attributes	Sorghum (Indo-Pak varieties)	Sorghum (Nigerian varieties)	Maize
Crude protein %	8.9-9.5	10.4-10.5	9.65-9.75
Dry matter ??	92.50-92.78	93.40-93.52	90-91.5
Organic matter ??	-	93.06-93.1	90.53-90.80
Crude fiber ??	2.70-2.80	2.01-2.1	1.9-2.0
Ether extract ??	2.50-2.60	2.97-3.0	3.98-4.10
Ash ??	1.20-1.30	6.94-7.0	3.5-9.0
Gross energy (Kcal/kg)	4100-4105	4120-4130	4140-4150

Table 2: Percentage of sorghum used as an animal feed resource in different countries and regions [33].

Countries	Sorghum used as an animal feed resource (%)
China	58
USA	62
Indo-Pak subcontinent	8-10
Asia	35
Worldwide	51

Table 3: Nutrition profile of forage sorghum (%) adapted from Iqbal *et al*. [10].

Dry matter (DM)	30-35
Crude protein (CP)	7-8.5
Crude fiber (CF)	30-32
Ether extract (EE)	1.5-2.0
Ash	6.8-7.2
Nitrogen free extract (NFE)	53-56

and water shortage is predicted to become from bad to worse in days to come [9]. This situation has made necessary to switch to those crops that require fewer water and yield more biomass. Sorghum requires less water to yield considerably high forage yield as compared to other summer forages like maize. In areas where there is a limited water availability, sorghum is one of the best choices as it requires 30-55% less water than maize [46]. It has higher water use efficiency and can tolerate moderate levels of moisture stress or drought [47]. Sorghum requires fewer fertilizers in comparison with maize without compromising the green forage yield [48]. Another factor which makes sorghum economical and cost effective in comparison with maize is the cost of seeds which is much cheaper than maize. As sorghum is a C4 crop, thus it has been predicted that with temperature rise, its production will increase. Furthermore, majority of soils in Pakistan are deficient in nitrogen and phosphorous [49], thus sorghum has been found to be the higher yielder of green forage than other summer cereals like maize in less fertile soils. Another advantage of forage sorghum is that it can be planted late in summer than maize without any reduction in biomass production if proper irrigation and fertilizers are to be applied. This late sowing of forage sorghum makes sure the availability of green forage for latter part of summer when there is a severe deficiency of forage for ruminants. Forage sorghum contains prussic acid which develops into hydrogen cyanide which reduces the quality of forage and is considered to be harmful for lactating animals and young calf. A variety of researches have demonstrated the fact that if forage sorghum is harvested at 50% flowering stage, then HCN contents are the minimum and in safer limits. However at earlier growth stages (up to 18 inches of plant height), there is high concentration of prussic acid. Like other cereal forages, sorghum is free from nitrate toxicity, however drought may result in nitrate toxicity if heavy nitrogen doses have already been applied. Forage sorghum is considered to be poor on nutritious scale, particularly in crude protein contents (7-8.5%) which are lower than forage maize (Table 3) [10]. The crude fiber and ash contents of forage sorghum are 30-32% and 6.8-7.2%, respectively. Forage sorghum quality may be improved by growing it in intercropping systems with different legumes such as cowpea, cluster bean and soybean. As legumes are rich source of crude protein and if these are grown in association with forage sorghum then the quality of mixed forage increases to a great extent particularly the protein contents. This is due to the fact that legumes contain more than double of crude protein than forage sorghum. Sorghum-legumes intercropping also results in higher biomass production than sole cropping of sorghum. Furthermore, breeding has gone a long way in developing hybrids and various traditional varieties which have higher protein contents. Brown midrib (BMR) is a genetically modified sorghum in which midrib size and mass has been reduced to increase the crude protein contents. As midrib in leaves of traditional varieties reduces the protein contents, thus its reduction has resulted in a significant increase of crude protein contents

even in the range of 9.5-10%. Thus forage sorghum has been proved to be the best alternate of other cereal forages being the most economical one along with being the most heat and drought resistant crop.

Sorghum Fodder Preservation as Hay and Silage: With the development of science and technology, human have learnt to cope with adverse environmental conditions and even to utilize them for their benefit. Forages are the cheapest and most relished animal feed resource and produce excess of green forage when climatic and other conditions are conducive for their growth and development. Similarly during extreme temperature hikes and plunges, forage become deficient and ultimately lactating animals are underfed [50]. The net result is the sharp decrease in milk and meat production which compromises human food security. Thus sustainable forage production goes a long way in ensuring animal nutrition and ultimately human food security. In order to ensure the sustainable supply of forages to milch animals even during temperature extremes, hay and silage making techniques were developed which may be declared as the top inventions of the century as far as dairy science is concerned [51]. Fodders are the crops that are grown and preserved as hay or silage and then fed during intervals when there is shortage of green forage. Fodders preservation as hay and silage has helped to sustain milk and meat production that used to get a nose dive during temperature extremes due to non-availability of green forages. Hay is the air dried fodder, while silage is the fermented fodder prepared under anaerobic conditions with the addition of some supplements like urea and molasses. The crops with thin stems are preferred to be preserved as hay because it is much easier to shade dry thin stemmed crops as compared to thick stemmed crops. Legumes such as cowpea, cluster bean and soybean have thin stems and best suited to be preserved as hay. Thick stemmed crops like cereal forages are best suited to be preserved as silage [52-57]. Silage preparation technique involves harvesting of crop on appropriate stage, cutting into pieces and then pressing them tightly. The structures used for making silage are called silos and these are prepared in different shapes and forms of different materials. Urea and molasses are added to increase the fermentation process rate and to increase the quality of silage. Lactic acid is produced and its concentration determines the quality of silage. The presence of oxygen in silos disrupts fermentation process while butyric acid production increases and resultantly silage quality is deteriorated [13]. Excessive heating may result in browning of silage which is not of good quality silage. The color of best quality silage is from golden to mild brown color. The preserved fodder as silage provides excellent quality feed to lactating animals during periods of green forage shortage. Sorghum fodder holds advantage in way that it can be preserved as hay as well as silage and is considered to be the best alternate of maize silage. The matter of fact is that silage making is quite a technical job as it requires careful calculation of each and every step from crop harvesting to closing of silos and maintaining the anaerobic conditions [13]. But hay making is much easier to perform and best suited in climatic conditions of Pakistan as there are no frequent rains and abundant sunshine makes hay making even more feasible. Animals in Pakistan continue to suffer from malnutrition particularly during May-June and November-December during which green forage shortage causes reduction in milk and meat production. Thus the need of hour is make these fodder preservation technologies in the excess of dairy farmers and in this context, the role of provincial agriculture and livestock departments is at the core of strategy. Farmers are needed to be made aware of the importance of these technologies in ensuring sustainable fodder supply so that there is no decline in milk and meat production. Hay and silage making techniques are of the most importance for Pakistan as the milk production in Pakistan is much less as compared to number of animals and their known potential, but forage supply is the limiting factor. Thus excessive forage preserved as hay and silage is bound to increase milk and meat production and only thing required to realize this dream is the awareness at farmers as well as government level. It is a matter of grave concern that dairy farmers in Pakistan continue to remain ignorant about these fodder preservation techniques and net result is colossal loss of resources and money due to reduced milk and meat production. Thus the need of hour is to make cumulative efforts at dairy farmers and government levels to make full utilization of these techniques in order to ensure the sustainable fodder supply for animals. Only by including hay and silage in animal feed resource will ensure animal feed diversification and this will go a long way in ensuring food security for teeming millions.

CONCLUSION

Sorghum is a multipurpose crop in true sense as it has the potential to satisfy diverse human needs as well animal dietary needs. The changing scenario of

agricultural water availability in Pakistan and emerging global warming phenomenon has further aggravated the necessity of fitting this crop in cropping systems. Sorghum is much economical to grow as compared to other crops like maize which makes it one of the best alternate because everything revolves around economics in agriculture. Sorghum utilization in food products may help to reduce malnutrition in world generally and in Pakistan specifically. As farmers in Pakistan have small land holdings, so they can ill-afford to apply all inputs in appropriate quantities and resultantly there is a huge yield gap between production and potential. Sorghum has the potential to give considerable higher yields of green forage as well as grain with less use of inputs. Thus forage sorghum has the potential to increase the productivity of milch animals in Pakistan and ultimately it will ensure white revolution in terms of milk production keeping in view the large number of ruminant animals and their high known potential. Thus it can be declared that sorghum crop is the future of Pakistan as far as animal and human dietary needs are concerned.

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