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DATE PALM RESIDUES AS AN ALTERNATIVE SOURCE OF ANIMAL FEED IN SAUDI ARABIA

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SUMMARY

There are a limited number of cultivated forage species in Saudi Arabia. The most common forage species is alfalfa (*Medicago sativa* L.). Therefore, hay production in the country is reliant on alfalfa and a few grass species. However, there is a tendency to standardize the productivity of this crop in the Kingdom due to its high water requirements. Large quantities of barley seed (*Hordeum vulgare*) are imported annually at exorbitant prices to meet the increasing demand for animal products. In addition, each of the important forage crops that are characterized by low water requirements compared to alfalfa, clover, and with its tolerance to heat and salinity, and high-energy content (carbohydrates). Thus, it is crucial to introduce other forage sources such as using silage to bridge the deficit in local forage crop resources. Silage is not commonly utilized as a source of animal feed among animal producers in Saudi Arabia, due to the lack of interest among animal producers. Thus, the aim of this review is to present information about the silage industry and the possibility of making silage from date palm residues as an alternative source of animal feed in Saudi Arabia.

Key words : Saudi Arabia, forage production, animal Feed, silage Preparation, date palm residues

Animals require a continuous supply of feed all year around. Yet, in many areas of the world, countries have a limited source of forage production. This may be due to cold temperatures during winter or the country being dominated by a desert environment, which is then dependent on irrigation for growing forage crops. Under these circumstances, it is difficult to provide animal feed all year around. The Kingdom of Saudi Arabia is an arid region, dominated by desert environments (with extremely high temperatures in summer and mild, dry weather in winter). At the same time, Saudi Arabia is one of the fastest growing animal feed markets in the Middle East (Market Research Report, 2019). Animal feed requirements in the Kingdom are estimated at 13.7 million tons, of which 7.35 million tons are available, including pastures and irrigated feed crops (Statistical book for the Ministry of Environment, Water and Agriculture 2007). Almost 10,021,675 heads were slaughtered inside Saudi Arabia during the period 2014–2018 (The General Authority for Statistics in Saudi Arabia in 2018). The main sources of animal feed in Saudi Arabia are alfalfa and a few grass species such as Rhodes grass (*Chloris gayana*) and Sudan grass (*Sorghum bicolor*). Alfalfa is a crop with high water demands. Although irrigation could increase forage production, the consequence of excessive irrigation has resulted in declining water levels, soil salinization, and desertification has become a major crisis in some areas of the country.

Forage preservation plays a critical role in providing a high nutritional value for livestock worldwide. One of the most important forage preservation methods in Europe and USA is silage production. Hence, silage is an alternative solution for feeding animals in Saudi Arabia. The aim of this review paper is to present information about the silage industry and the possibility of producing silage from date palm residues as an alternative source of animal feed in Saudi Arabia.

Introduction to Silage

Silage is preserved forage that is prepared for storage under anaerobic conditions. This anaerobic environment is essential for the fermentation process, which produces a good conservation feed that is eventually reflected in animal production. Ensilage is the name given to the process, and the container used is called the silo. Table 1 describes the main characteristics of the most common silos types (sourced from Perry *et al*., 1999).

Silage was established thousands of years ago. The term “silo” is derived from the Greek word “*siros*,” which means “pit or hole sunk for storing corn” in English. McDonald (1981) describes the historical development of silage in the world. He indicates that the knowledge of ensilage as a forage conservation technique was known in many parts of the world. The Egyptians (c.1000–1500 B.C) were familiar with ensiling as a means of preserving crops. The Roman historian Cato (approximately A.D 100) reported that forage had been stored by the Teutons. Ensiling of wilted grass has been practiced for at least 700 years in Italy. In Northern Europe, such as Sweden, Russia, and the Baltic provinces, grass has been ensiled since the beginning of the eighteenth century.

Currently, techniques in silage production have improved to meet the quality that livestock producers need. Thus, to develop the silage industry and meet the nutrient requirements in livestock enterprises, it is important to understand the steps of the silage process.

Silage Preparation

Producing silage includes many steps, starting in the field and culminating in the animal’s consumption. Harvesting the forage crop is the first step in making silage. Knowing the best stage to harvest helps to produce crops with the highest nutrient values, which will reflect on silage quality. For example, legumes should be harvested when the crop growth is between the budding to early bloom stage of development. At this stage, the crop has reached the optimum content in neutral detergent fiber (NDF), dry matter (DM), and moisture. The recommended harvest time for alfalfa is that when the plant fiber is at 40% (Bucholtz, 1999). In contrast, grasses contain less moisture and higher fiber than legumes, and the recommended harvest time is in the early heading stage. Miller (1984) summarizes the first harvest of various forage species used for producing silage (Table 2). The length for chopping the forage crop differs depending on the species. For instance, the cutting height for corn silage ranges between 4 to 6 inches (120–180 cm). At this height, a high quality silage may be obtained (Kung and Neylon, 2001).

TABLE 1

The types of silos that are more commonly used to produce silage.

Horizontal Type	Vertical or Upright Type (Tower silos*)*
Trench	**Conventional upright**
a. Consists of trenches dug into the side of the hill. **b**. Has many different sizes, but typically ranges from 10-40 ft in depth, 15-50 ft in width, and 100–300 ft in length. **c**. Floor and walls may vary from plain dirt to concrete **d**. A tractor is usually used to pack the silage as the silo is filled. **e**. The silage is usually covered with a heavy weight polyethylene film. **f**. Usually emptied from the lower end to the upper end using a tractor.	**a**. All upright silos are cylindrical in shape. **b**. Conventional upright silos are constructed of reinforced poured or of concrete staves. **c**. Conventional upright silo sizes vary, but typically range from 18-50 ft in diameter and 40-80 ft in height. **d**. It is normally unloaded from the top, usually with a mechanized unloader. **e**. Conventional upright silos are usually emptied before being refilled. **f**. For effective preservation ensilage, the ensiling should contain 25-40% DM.
Bunker	**Airtight or sealed silos (Limited oxygen)**
a. This type of silo is sometimes used on very flat, rocky, and/or pervious soil. **b**. The sidewalls are usually made with posts and boards lined inside with building paper or plastic film. The floor is concreted, and the ends are left open.	**a**. Constructed of protected metal with rubber-cemented joints. **b**. They are completely airtight. **c**. The sizes range from 18-40 ft diameter and 40–100 ft in height. **d**. Forage varying in dry matter content from about 25-75% may be effectively preserved and stored in an airtight silo.
Weenie bags	
a. A temporary silo, can serve as a one-time storage facility for silage. **b**. Plastic tube (100-foot long). Holds 100 tons of silage, with no spoilage, as long as the tube is not punctured. **c**. Fairly expensive.	

Source : Perry *et al.* (1999).

TABLE 2
Summary of when to harvest various forage species and mixtures to optimize quality, yield, and persistence of silage.

Species	Species Type	First harvest	Regrowth
Alfalfa	Legumes	Bud or first flower	Bud or first flower
Alfalfa+orchard grass	Legumes+grass mixtures	When orchard grass heads	Bud or first flower
Red clover	Legumes	First flower to 25% bloom	First flower of red clover
Red clover+grasses	Legumes+grass mixtures	When grasses head early	First flower of red clover
Ladino (white clover)	Legumes	10 to 50% bloom of ladino	Every 30 to 35 d
Ladino+grasses	Legumes+grass mixtures	10 to 50% bloom of ladino	Every 30 to 35 d
Birdsfoot trefoil	Legumes	10 to 50% bloom of birdsfoot	10 to 50% bloom of birdsfoot
Birdsfoot trefoil+ grasses	Legumes+grass mixtures	10 to 50% bloom of birdsfoot	10 to 50% bloom of birdsfoot
Smooth broom	Grass	When heads emerge	Vegetative
Orchard grass	Grass	When heads emerge	Vegetative
Timothy	Grass	When heads emerge	Vegetative
Reed canary grass	Grass	Flag-leaf to early heading	Every 30 to 40 d
Tall fescue	Grass	Flag-leaf to early heading	Every 30 to 40 d

Source : Adapted from Miller (1984).

Silage Crops

Silage is made from any crop that can be used in green forage or hay. However, silage crops must be selected based on their agronomic and nutritional quality characteristics, moisture content (stabilized between 60-70%), and high DM content.

Corn (*Zea mays*) is considered the perfect silage crop since its seeds contain a high carbohydrate content and the DM content ranges between 28–42%. Sorghum is another crop that is becoming more important for making silage under dryland environments. Alfalfa has a high concentration of organic acids, minerals, and protein, making it a more suitable legume crop for silage (Al-Ghumaiz *et al*., 2006).

Other legume pasture species that could possibly produce good quality silage are Red clover (*Trifolium pratense L.*) and White clover (*Trifolium repens L.*). Several pasture grass species are considered good silage crops, namely Bermuda grass (*Cynodon dactylon L.*) Orchard grass (*Dactylis glomerata L.*), Smooth bromegrass (*Bromus inermis* Leyss), Timothy (*Phleum pratense L.*), and Tall fescue (*Festuca arundinacea* Schreb). Cereal grain species including Barley (*H. vulgare L.*), Oat *(Avena sativa L*), and Triticale have been used for silage, due to their nutrient quality producing a good silage (Khorasani *et al.*, 1993). In addition, silage can be prepared from plant residues, such as discarded vegetable plants and fruit crops or date palm residues.

Silage Process

After the forage mass is packed tightly into the silo, and depending on the availability of oxygen inside the silo, chemical changes occur in the forage owing to the aerobic and anaerobic phases.

Aerobic Phase

The aerobic phase occurs in the presence of oxygen, immediately after crop harvesting. The plant cells remain alive for a period, and aerobic bacteria will increase as long as oxygen is available. In the first few days, plant enzymes and microbes become active; then, the enzymes (or proteases) consume the carbohydrates, causing the release of carbon dioxide and heat.

Anaerobic Phase

The anaerobic phase, also known as the fermentation stage, occurs inside the silo in the absence of oxygen. Many anaerobic bacteria are active in an oxygen free environment (*Lactobacillus* spp. or lactic acid bacteria, LAB) and start to consume the carbohydrates, fermenting and changing them to organic acids. Lactic acid is an important acid that drops the pH to about 3–5, which stops microbial activity, thereby maintaining the silage in good condition and more palatable to animals (Table 3). The moisture content needed for producing good silage is between 60-70%.

Undesirable microorganisms can occur, such as clostridia bacteria, which grow in a high moisture and high pH environment. These bacteria are inoculated into the silage via their spores, causing mold, and decreasing the nutritional quality or suitability of the silage for animal consumption. Low pH and a lack of oxygen may be a way to prevent the growth of yeast and molds. Thus, in order to produce a high quality silage, the packing process must to be done as quickly as possible to exclude oxygen, by producing lactic acid, and reducing the pH to 3–5, thereby keeping the silage in a good condition with a high nutrient content. Table 3 presents a summary of aerobic and anaerobic metabolism (sourced from Al-Ghumaiz, 2006).

Fermentation Analysis

Fermentation analysis is used to evaluate silage quality. A silage fermentation report evaluates different parameters, including DM, acidity and alkalinity of silage (pH), titratable acidity, ammonia, lactic acid, acetic acid, propionic acid, butyric acid, and isobutyric acid. Ward (2000) indicated in his paper, “This information may be valuable in certain situations as a rapprochement ‘report card’ to discover silage fermentation mishandling.” However, fermentation analysis has limited information for rationing purposes. Additionally, the outcome of fermentation is significantly related to the DM content of the silage. Therefore, DM content could be determined by the total and type of acids present. Table 4 presents the average values of legume and grass silage following fermentation analysis (sourced from Ralph, 2000). From table 4, the data shows that most parameters vary significantly depending on the DM content of the plant; for example, parameters differ between 30% and 38% DM content in the legume silage. However, there appears to be no significant difference in the pH of the legume silage between a DM content of 28% and 52%. In grass silage, the pH remained stable across the range of DM content. In the total acid content, there is no difference between legume and grass silage. Overall, when comparing the fermentation results of the legume and grass silage analysis, there appears to be no significant difference between them (Table 4).

The Silage industry in Saudi Arabia

Making silage is not a common practice among local animal producers in Saudi Arabia. Furthermore, preparing silage is costly as well as complicated, and requires a basic knowledge of handling and storage when compared with hay or green forage. Therefore, local animal producers have no interested in adopting such methods. However, large companies in the country are using corn silage for their own purposes. For example, Forde (2017) reported that 52 silage pits had been established on a local dairy farm belonging to Almarai’s farms in Riyadh, Saudi Arabia.

Recently, and due to high water demands, the Saudi government has reduced its domestic production of some important crops including alfalfa and corn (Putnam et al., 2017). Thus, making silage from such crops will be impossible, and yet the demand for animal feed is still high. Preparing silage from plant residues might be a solution to bridge the deficit in local forage crop resources.

TABLE 3
Summary of silage processes during aerobic and anaerobic metabolism

Aerobic Metabolism	Anaerobic Metabolism
Pre-seal phases	Filling and packing
↓	↓
Availability of oxygen	Free of Oxygen + Optimum moisture
↓	↓
Respiration phase	Anaerobic bacterial activity
↓	↓
Aerobic bacterial activity	Fermentation Phase
↓	↓
Loss of nutrients	Produce acids such as lactic acid
↓	↓
Release of carbon dioxide, heat, and water	Low pH (3.5/5)
↓	↓
Proteases	Stops bacterial activity
↓	
Maintains forage mass	

Source : Al-Ghumaiz (2006).

TABLE 4
Comparison between the average values of legume and grass silage following fermentation analysis (based on the DM range)

Dry matter range (%)	pH	Titratable acidity (meq/g)	Lactic acid (% of DM)	Acetic acid (% of DM)	Propionic acid (% of DM)	Butyric acid (% of DM)	Total acid (% of DM)	Lactic acid (% total acids)
A. legume silage								
<24	5.39	3.77	3.04	4.18	0.64	2.10	10.0	30.5
24-28	3.86	4.45	4.26	0.61	1.64	1.61	11.0	40.7
28-32	4.91	4.63	4.87	3.80	0.33	0.91	9.9	49.1
32-36	4.84	4.38	5.26	2.96	0.15	0.15	8.7	60.4
36-40	4.70	3.97	4.95	2.15	0.09	0.20	7.4	67.0
40-44	4.76	3.44	4.83	1.62	0.06	0.09	6.6	73.2
44-48	4.77	3.25	4.42	1.45	0.04	0.01	5.9	74.7
48-52	4.90	2.47	3.39	1.04	0.03	0.05	4.5	75.2
>52	5.50	2.01	2.06	0.68	0.04	0.02	2.8	73.6
B. Grass silage								
<24	5.03	5.25	3.34	4.02	0.72	1.60	9.7	34.5
24-28	4.73	5.79	4.49	3.15	0.37	0.81	8.8	50.6
28-32	4.51	5.48	4.57	2.49	0.25	0.40	7.7	59.3
32-36	4.57	4.45	4.72	2.05	0.13	0.34	7.2	65.2
36-40	4.59	3.60	4.59	1.59	0.14	0.16	6.5	70.8
40-44	4.60	2.93	4.09	1.10	0.03	0.05	5.3	77.6
>44	4.85	2.31	2.90	1.10	0.03	0.02	4.1	71.6

Source : Adapted from Ralph (2000).

Saudi Arabia is recognized for its high production of dates from different date palm varieties. Over the past three decades, Saudi Arabia has been recognized as producing the largest supply of dates in the world (El-Hag *et al*., 1993). According to “The General Authority for Statistics in Saudi Arabia in 2018,” over 28 million palm trees in the country produce more than 1.4 million tons of dates. Thus, the massive numbers of palm trees produces a vast quantity of residues, such as fronds (leaves), obtained in the annual slump stage, as well as atrophied dates and nuclei. In addition, there is an abundance of low quality date palms (discarded dates) that can be utilized as a source of animal feed. Few studies have discussed the possibility of using date palm byproducts as animal feed. Al-Dobaib *et al*. (2009) found that in hot climatic regions, discarded dates are more likely to be used in feeding small ruminants. Additional observations have shown that there may be an advantage for rabbit producers to replace the concentrates in the rabbit’s diet with discarded dates (Al-Dobaib *et al*., 2007).

Preparing Silage from Date Palm Residues

The residue of date palms include fronds (leaves), discarded dates, atrophied dates, and nuclei. During silage preparation, date palm residues are chopped and minced (using a mincer) prior to being packed into the silo. The moisture content of the chopped material should range between 60–70%. As indicated previously, packing should be done by placing the chopped materials into the silo while simultaneously pressing out all the air as the silo is filled. This process is important for any silo type or ensiled materials and is correlated with the exclusion of oxygen in the silo. Thus, a low packing density can affect silage quality by losses of DM during storage (Ruppel *et al*., 1995). The piles of stacked residues are then covered with a plastic layer and left for two months during which time anaerobic fermentation is completed. The amount of lactic acid produced is based on the carbohydrate content in the ensiled materials. The pH level should drop to about 3–5, which will stop microbial activity and keep the silage in good condition.

Silage from date palm residues may not be good as corn silage. As indicated above, silage requires a moisture content of 60–70%. This moisture level cannot be reached in some dry date palm residues such as fronds (leaves) without adding water to the dry forage. Jones *et al*., (2004) suggested adding water to the dry material to enhance the fermentation process. Moreover, the carbohydrate content in the date palm residues (palm fronds, discarded dates, and nuclei) are insufficient and lower than that in some cereals crops (e.g., corn and barley seeds; (Table 5), causing anaerobic bacteria to be less active, which leads to a low lactic acid value, and eventually producing a low quality silage. In this case, fermentation stimulants can be added as a silage additive. Liquid inoculants may increase the lactic acid bacterial population, thereby increasing the rate and extent of fermentation. Molasses or cereal grains can be added to enhance the fermentation process. Enzymes can indirectly act as fermentation stimulants to improve the chance of the pH declining, and preventing clostridia fermentation (Jones *et al.*, 2004). The level of crude protein (CP) is higher in discarded dates than that in corn cereal crops, while the CP content in palm fronds, discarded dates, and nuclei is lower than that in corn and barley seeds (Al-Dobaib and Kamel, 2006; (Table 5).

After the fermentation process is completed in the silo, the silage is unloaded from the silo to use as animal feed. The feed out technique involves simply removing the daily requirement of the silage from the bunker and preserving the quality of the remaining unused silage for the next feed. However, removing silage layers will allow air to penetrate into the remaining silo face, which will affect silage quality. Therefore, it is important to use proper techniques during silage feed out. The technique is to remove about five inches per day and recover the remaining silage.

TABLE 5
Chemical composition of palm waste compared to corn and barley seeds

Source	DM	Ash	CP	Carbohydrates	CF	EE
Palm fronds	93.7	8.9	6.1	49.7	29.8	2.1
Discarded dates	87.4	10.4	20.7	30.1	38.3	3.4
Nuclei of dates	83.7	2.1	6.5	60.9	16.5	8.6
Corn seeds	89.6	2.5	10.1	82.6	1.6	3.2
Barley seeds	93.2	3.1	11.4	78.7	4.5	2.2

DM = dry matter; CP = crude protein; CF = crude fiber; EE = ether extract
Source : Adapted from Al-Dobaib and Kamel (2006).

CONCLUSIONS

Silage is preserved forage as a source of nutrition for animals. It can be used in many areas that have an unsuitable growing season for forage crops. Currently, silage is considered one of the most important sources of the forage industry. Corn is considered one of the best sources of material for producing silage due to the high carbohydrate content in its seeds. In arid areas, such as Saudi Arabia, sources of crops that can be used for silage are limited. At the same time, the country has an abundance of palm trees producing a huge quantity of residues. Therefore, the possibility of utilizing such residues to produce a good quality silage are high. The process of producing date palm residue silage is similar to producing corn silage. However, quality differences might favor corn. Adjusting the moisture content and adding silage additives will help to produce a date palm residue silage similar to corn silage. It is evident from the present review that producing silage in areas with limited sources of silage crops is not an obstacle as long as the area has abundant and cheap plant byproducts available like date palm resides.

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