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Nutritional Evaluation of Various Stages of Maturity of Oat Hay and its Effect on Milk Production and Composition in Lactating Holstein Friesian Cows

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MM and MT conceived the idea, conducted research and wrote the manuscript. SJ assisted in manuscript writing and data analysis. MIA, IG, NA and AS assisted in data analysis and reviewed the manuscript.

Key words
Oat hay, Harvest maturity, Nutritive value, Holstein Frisian cow, Milk yield, Milk composition.

ABSTRACT

The study was conducted to determine the effect of three harvest maturity stages on nutritive value of oat hay and milk yield and composition. Total of 9 Holstein Friesian lactating cows with nearly similar lactation stage and body weight were fed on three rations with proportions of 40% oat hay from different maturity stages *i.e.* boot, flowering and dough and 60% total mixed ration. The results showed that animals fed with oat hay from flowering stage (ration II) had significantly higher (P<0.05) dry matter (DM) intake followed by dough (ration III) and boot stage (ration I). Similarly, intakes of crude protein (CP) and crude fat (CF) were significantly higher (P<0.05) on ration II compared to rations I and III. Neutral Detergent Fibre intake (Kg/day) in rations I, II and III was 5.4, 6.8 and 6.19, respectively. Intake of Acid Detergent Fibre (Kg/day) was higher in ration II while lower in ration I. Acid Detergent Lignin intake (Kg/day) in three rations ranged from 2.26 to 2.61. *In vitro* DM digestibility (%) significantly increased (P<0.05) in ration II compared to ration I and III. Intake of minerals (g/day) of Calcium and Magnesium did not vary significantly, however intake of Manganese, Copper, Zinc and Ferrous decreased with advancement in oat growth. Milk yield (Kg/day) from rations II was significantly higher (P<0.05) than rations I and III, while milk composition was not significantly affected. The DM yield of oat hay was significantly higher (P<0.05) at dough stage. It was concluded that good quality of oat hay and higher milk production could be attributed to the flowering stage of harvest maturity.

INTRODUCTION

Livestock industry contributes 57.8% to agriculture and 11.8% to the National Gross Domestic Product (GoP, 2015-16). Fodder availability throughout the year is a basic requirement for optimizing animal productivity (Uzun, 2010). Animals in Pakistan are generally underfed, particularly in the dry seasons, resulting in lower yield and fertility. However, feed scarcity can be copped by preservation of fodders in form of hay and silage (Iqbal *et al*., 2009; Drew, 2015). Livestock, in Pakistan is mainly stall fed. Crop residues and fodders are fed to animals. Agriculture land is limited and therefore increased fodder availability throughout the year is possible only through increasing yield per unit area and preservation of surplus fodders in order to maintain production at high level (Iqbal *et al*., 2009). Generally availability of fodder is high in the spring. Therefore, to avoid wastage of fodder and optimizing animal productivity, fodders can be stored as hay or silage for feeding during scarcity periods throughout the year.

Hay from grass forage is a vital constituent of animal feed because it is economical source of digestible fibre, protein and minerals (Kokten *et al*., 2009; Anjum and Cheema, 2017). The wheat grain, barley, oat, rye and triticale are imperative feeds because of their yield and nutritional value. These crops are sowed at start of winter and harvested at the end of spring (Collar and Aksland, 2001). Four different growth stages of small cereal forages are generally known for yield, *i.e.* early boot stage, flower, milk and soft dough stage. One of the major factors that affect the nutritional value of plant to be used as forage is the stage of maturity at which it is harvested. There is great variation in oat hay yield and nutritive value of cereal forages depending on stage of plant growth that beasts for harvest (Lloyed, 1961).

Oat (*Avena sativa* L.) is one of the main cereal feed crops grown in November, December in all over Pakistan.

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It is fast rising, luscious, edible and nourishing crop. Oat is mainly fed as green and excess is preserved as hay for feeding during crop scarcity period. Its stem is flexible and greater to the stem of the wheat and barley. Nutritive value of oat hay such as total digestible nutrient, protein, fat, minerals and vitamin is high and appropriate. Therefore, oat forage is an important feed for dairy ruminants and small breeding animals (Hussain *et al*., 2002).

The production of hay can sustain livestock productivity during feed scarcity periods of the year. Due to high yield, lower moisture content, high nutritional value and lower losses of leaves during drying, oat is a good crop for hay making. However, information on selecting the appropriate harvesting time of oat for hay making is limited. Therefore, the present research was planned to examine the suitable stage of harvesting oat for hay making in term of nutritive value, oat yield, milk production and composition of dairy cows. Such data could be useful in selecting the appropriate harvesting or grazing time for attaining the highest yield or quality forage in oat hay.

MATERIALS AND METHODS

Description of oat crop and harvest maturity

From the fodder site of Dairy Farm, University of Agriculture Peshawar Pakistan, three oat plots were selected. Previously all plots had been harvested twice; however the third cut was used for hay making. Each plot consisted about 21760 square feet area. All plots were cultivated randomly in October, 2013 at a seed density of 20 kg/plot. Before cultivation of the oat crop the plots were fertilized with farm yard manure (FYM) at the rate of 375 kg per plot. After cultivation and first watering, all pots were fertilized with urea at the rate of 25 kg/plot. After taking each cut, plots were again fertilized at the rate of 25kg urea /plot. During growing season a total of 75 kg urea was used for each plot. The third re-growth harvest was taken at three stages of maturity i.e. boot, flowering and dough and sun dried. Boot stage: oat forage was cut at boot stage, two weeks before flowering stage. Flowering stage: Oat plots were cut at flowering stage, which is the normal maturity stage for oat hay preparation. Dough stage: Oat plots were cut after flowering at mature seed stage.

Harvesting procedure

The oat plots were cut manually with the help of sickle. The harvesting was done on sunny day at 9:00 am for each plot. The weather forecast was also checked whether it was sunny, cloudy or rainy for at least three days after cutting because sun shine is the basic requirement for making good quality hay. Oat crop was harvested at the height of 5cm from the ground level. The harvested fodder was weighed and fresh yield per plot was determined by using the following formula:

Fodder weight (kg) =
Loaded vehicle weight (kg) - Empty vehicle weight (kg)

The fodder was spread over the ground for drying. The fodder with 30-40% moisture was shifted to a well-ventilated store to make it safe from any dust, rain, and development of moulds. Representative samples (n=5) from each plot were taken randomly from fresh and dried (hay) forage. The samples were kept in properly labelled plastic bags and processed for further chemical analysis.

Animals and experimental design

The feeding trial was conducted at the University Dairy Farm. Nine Holstein Friesian lactating cows were selected from the dairy herd on the basis of nearly similar lactation stage and body weight. The animals were blocked into three groups based on body weight, lactation stage and milk yield. The animals were fed a total mixed ration (60%) according to the routine feed formulation of the farm, while about 40% of the total fed DM was from oat hay. The three diets were similar in the ingredients composition except the quality (harvest maturity) of the oat hay. The three diets contained 40% oat hay harvested at three stages of maturity (boot, flowering, dough stage). The ration was offered twice a day (7:00 AM and 4:30 PM). The experiment was continued for 21 days with 7 days adaptation period and next 14 days for data collection.

Milk sampling and chemical analysis

Dry matter intake and milk yield of each animal (milked two times daily: 06am and 6pm) were recorded daily. The milk samples were pooled with 1:1 to obtain two composite milk samples and stored at 4°C.

The hay samples were separated into two parts; one part (500 g) was dried at 60° C and remaining portion was stored cooled. The dried samples were ground to a particle size of 1 mm by using Thomas Willey mill, labelled and stocked in dry plastic bags. The DM content of the fresh and air dried samples, ash content and CP were determined according to AOAC (1999). Fibre fractions such as NDF, ADF and ADL were determined according to van Soest *et al*. (1991). Samples were analyzed for Ca, Mg, Fe, Cu and Zn using atomic absorption spectrophotometer.

In vitro dry matter digestibility (IVDMD) of oat hay was determined with two stage *in vitro* method described by Tilley and Terry (1963). Cow steer fitted with permanent ruminal cannula fed a mixture of maize fodder and wheat straw was used for collection of rumen liquor to carry out in vitro incubation of herbages. Incubation of samples (about 0.3 g) was carried out in triplicate. The filtered rumen liquor was mixed with McDougall's buffer in 1:3 proportions. Tubes containing 40 ml aliquot were incubated in laboratory incubator at 37°C for 48 h. Three blank tubes without sample were also included in each run. All the possible measures were adopted to maintain anaerobic conditions during procedure and incubations. The contents during incubation were mixed two times by gentle shaking at 12 h interval. On termination of incubation, the tubes were centrifuged at 3000 rpm for 15 min. The supernatant was discarded carefully. The tubes with precipitate after drying at 70 °C for 48 h were cooled and weighed. The IVDMD was calculated using the equation:

$$\text{IVDMD (\%)} = \frac{\text{Initial DM input} - (\text{Residue} - \text{Blank})}{\text{Initial DM input}} \times 100$$

Where, IVDMD is *in vitro* dry matter digestibility

Crude milk protein was analyzed using the Kjeldahl method as a reference (IDF Standard 29, 1964; IDF Standard 20B, 1993). Digestion and distillation were performed with a Kjeltec Auto 1030 Analyzer (Tecator, Höganäs, Sweden). Milk fat content was analyzed according to Gerber method (IDF Standard 152, 1991) and lactose was analyzed according to AOAC (1990) (ML; method 972.16) using infrared spectroscopy (0-scan 605, Foss Food, Denmark) while total solids were determined by oven drying (IDF Standard 21A, 1982).

Statistical analysis

The effect of oat hay harvest maturity on the nutrient composition, nutritional value, rumen degradation kinetics, milk production and milk composition were determined using PROC MIXED Procedure (Littell *et al*., 2006) of Statistical Analysis System (SAS, 2009). Oat hay harvest maturity and animals were considered as random effect. The following model was used:

$$Y_{ij} = \mu + \beta_j + \epsilon ij$$

Where, Y_{ij} is yield or response of the treatment, μ si overall mean, βj is treatment effect; treatment comprises 40% oat hay in ration, harvested at boot, flowering, dough stage of maturity and ϵ_{ijklm} is random error

RESULTS AND DISCUSSION

Dry matter, crude protein and crude fat intakes in oat hay

The Holstein Friesian dairy cows were fed with oat hay prepared from three different harvest maturity stages (boot, flower and dough) mixed in total mix ration (TMR) as shown in Table I. The experimental rations were 40% of oat hay prepared from different maturity stages of forage and 60% of TMR. Holstein Friesian dairy cows fed on oat hay from forage harvested at flowering stage had significantly (P<0.001) increased in dry matter intake (DMI) followed by dough and boot stage. The mean values for DMI for ration I, II and III were 9.293, 11.409 and 9.452kg, respectively. Comparing oat with barley, higher DM intakes were reported with cows fed oat and barley, but lower for cows fed corn silage although no difference in body weight change was observed by Burgess *et al*. (1973).

The mean crude fat intake determined by feeding trial was 734.43, 748.53 and 722.50 g for ration I, II and III, respectively (Table I). The maximum crude fat intake was observed for ration II comprising oat hay from forage harvested at flowering stage while ration III composing oat hay from dough stage had the lowest crude fat intake. The CP intake in three experimental rations also depicted similar pattern across harvest maturity stage.

Table I.- Intake of dry matter (kg/day), crude fat (g/day) and crude protein (g/day) in oat hay from different harvest maturity stages.

Ration	Oat hay stage	Dry matter	Crude fat	Crude protein
I	Boot	9.293^b±12.13	734^b±11.86	1870^b±69.98
II	Flower	11.409^a±11.86	748^a ± 0.87	2083^a ± 79.98
III	Dough	9.452^b±14.23	722^b ± 5.11	1506^c ± 84.46

All experimental rations contained 60% total mixed ration (TMR) and 40% oat hay from different plant maturity stages. All values are Mean ± SE. Means with different superscripts within same column are significantly different.

Factors which influence forage quality are forage cultivar, stage of maturity at harvest and storage method. Secondarily environmental factors such as soil type and fertility, day length, temperature during plant growth are also important (Ball *et al*., 2000). Because of low energy value of oat hay, it is generally offered to dry cow or dry heifer. One of the reasons for its poor feeding value for dairy cows could be the maturity stage at which crop is harvested. Maturity has important influence on oat hay quality. Stages of growth or maturity are generally recognized for feeding strategies. At boot stage, nutrient content is higher while dry matter content is lower and therefore it reduces DMI. At flower stage, pollination and initial development of grain occur. Head elongates out of flag, plant gets green, dry matter content also gets high leading to more yield and DMI. At dough stage, water content of the kernel decreases to dough consistency, changing from soft to hard dough, crude fiber increases with advancement in maturity to milk stage and then decreases at dough stage leading to less feed intake. In the present study, overall feed consumption was lower for boot and dough stage and higher for flowering stage. The present results are according to the findings of Hingston and Christensen (1982); Keady (2005) and Huhtanen *et al*. (2007), who also described that oat hay at flowering stage, had higher DMI as compared to dough and boot stage. In contrast to our findings, McCartney and Vaage (1994) and Ahvenjarvi *et al*. (2006) reported low level of crude protein (CP) at flowering stage leading to lower DMI. The difference may be due to harvesting stage of oat for hay making. Intercropping and feeding of oat hay with moderate quantity of forage legume can be a good strategy to improve both quantity and quality of oat hay and increasing intake and body weight gain (Khalili *et al*., 1992).

Table II.- *In vitro* dry matter digestibility (IVDMD)(%) and intake of NDF (kg/day), ADF (kg/day) and ADL (kg/day) in oat hay from different harvest maturity stages.

Ration	IVDMD	NDF intake	ADF intake	ADL intake
I	62.83[c]±4.91	5.456[c]±91.73	3.842[c]±62.20	2.260[c]±68.33
II	81.47[a]±6.09	6.861[a]±79.11	4.579[a]±87.13	2.615[a]±31.30
III	71.00[b]±4.40	6.193[b]±67.72	4.275[b]±96.66	2.324[b]±23.90

Ration I, 60% total mixed ration and 40% oat hay prepared from boot stage of maturity. Ration II, 60% total mixed ration and 40% oat hay prepared from flower stage of maturity. Ration III 60% total mixed ration and 40% oat hay prepared from dough stage of maturity. All values are Mean ± SE. Means with different superscripts within same column are significantly different (P<0.05). NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL acid detergent lignin.

CP intake increased significantly at flower stage followed by boot stage and decreased with maturity of oat. Due to high DMI, oat hay had highest yield with good feeding value clearly demonstrates the inverse correlation of CP intake with oat hay growth maturity. Our results are not in agreement with findings of Mpairwe *et al*. (2003), who revealed that protein content is higher at boot stage because plant losses its protein content with maturity while dry matter production per acre is lower at same stage compared to flower and dough stage.

Maturity affects nutritive value more than many other factors. Boot stage of oat hay is the least palatable to livestock, and usually produces slower and less efficient gains than flower stage (Guyer *et al*., 1995). Although flower stage results in lower CP content, but it turns out the higher forage yield and typically the maximum total digestible nutrient (TDN) yield per acre. When varieties or weather conditions produce a short straw with low tonnage of forage, it is advisable to harvest at the early flower stage to take advantage of the grain produced. In the support of present findings, Brundage (1973), Christensen (1993) and McCartney and Vaage (1994) reported higher CP content at flower stage as compared to dough stage and therefore higher protein intake. For milking dairy animals, oat forages should be harvested as the first grain heads become visible in a field (late boot stage). Oat forage at this stage provides feed with high energy and protein content.

Intake of cell wall constituents and mineral and in vitro *dry matter digestibility*

Nutrient detergent fiber (NDF) intake (g/day) of oat hay in ration prepared from forage harvested at boot, flower and dough stage was significantly different (P<0.05) for the rations fed to the dairy cows by showing higher value (P<0.05) (6861.07±79.11) at flowering stage followed by dough (6192.97±67.72) and boot stage (5456.48±91.73). Similar pattern of intake of acid detergent fiber (ADF) and acid detergent lignin (ADL) in three rations was observed (Table II). In general, crop growth has great effect on quality of oat hay. With maturity of oat forage, dry matter yield and NDF, ADF and ADL increase while cell contents and CP in the whole plant and plant parts decreased (McCartney and Vaage, 1994; Ammar *et al*., 2004) and high cell wall contents are related with less DMI. Harvesting at early growth stage is critical to get high mass and nutritive value of forages (Malik *et al*., 2011). Therefore, a compromise is obligatory in cereal forage management for highest dynamics of plants and greatest forage yield of oat under various harvesting systems. The NDF content is an inconsistent because of different lignifications and it plays an important role in maintaining rumen ecosystem and rumen digestion (van Soest *et al*., 1991). NDF and ADF are interrelated to each other and conditions which are required to increase NDF would also increase ADF. In present study, NDF content increased from boot to flower stage which is supported by similar findings of Soita *et al*. (2002). In general, forage intake is assessed by cell wall content, while forage digestibility is linked with cell wall (neutral detergent fiber) content and its availability is estimated by lignification and other factors (van Soest, 1986). The ADF mostly contains cellulose, insoluble lignin and insoluble hemicelluloses. For estimation of fiber content in feed, mostly ADF is used as a quick technique. The ADF results of present study coincide with that of findings of Soita *et al*. (2002) and Turgut *et al*. (2008) who also reported high ADF intake at flowering stage of oat hay as compared to dough and boot stage. Lignin is mostly found in the primary cell wall or middle lamella rather than secondary cell wall (Jung *et al*., 1993). When plant becomes aged, lignin and cell wall content increase showing negative correlation with digestibility. Forage digestibility is affected by many factors and lignin is one of them. The lignin decreased with maturity of the forages because of grains to stem and leaf ratio. ADL intake was low at dough stage compared to early stage of oat. Our data is accordance with the findings of Stacy (1980), who also described increasing tendency of lignin with maturity of oat hay. The forages with high lignin content stay for longer period in the rumen due to slow rate of digestion, resulting reduced DMI and decreased animal performance (Allen, 2000).

Minerals intake (g/day) data was presented in Table III where no significant (P>0.05) difference was found in Ca and Mg intake while intake of Mn, Cu and Zn decreased (P<0.05) with increasing oat maturity stage. Oat harvested for hay making prior to soft dough stage contained appropriate amount of macro and micro minerals, which would meet the mineral requirement of dairy cows. The micro minerals like Mn, Cu and Zn reduced with advancement in oat crop maturity while Ca and Mg did not vary significantly with plant maturity in the present study. Similar observations were reported by Mayland *et al*. (1976) and Uzun (2010) on wheat and Bulbous barley. There were no apparent relationships of stage of growth and the calcium and magnesium levels and their effect on fiber levels were not affected by growth stage.

Table III.- Mineral intake (g/day) in oat hay from different harvest maturity stages.

	Ration-I	Ration-II	Ration-III	CV
Ca	417.85	417.87	417.99	0.076
Mg	134.42	134.19	134.06	0.182
Mn	46.19	45.23	44.78	0.720
Cu	7.17	6.43	5.93	0.624
Zn	7.21	6.89	5.91	0.677

CV, covariance. For details, see Table II.

Oat hay prepared from forage harvested at different maturity stages showed large variations *in vitro* dry matter digestibility (IVDMD) (Table II) with decreasing tendency of digestibility with advancing maturity. This could be related to the declining leaf: stem ratio and increasing fiber contents. Similar results were reported earlier (Wallsten and Martenson, 2009; Ammar *et al*., 2010). The present results are in agreement with Mayland *et al*. (1976), who also reported similar trend. Murray *et al*. (1996) suggested that oat crop should be harvested for hay at flower stage because of increased digestibility and feed intake at this stage compared to early growth stages.

Milk yield and milk composition

The milk yield (g/day) and milk composition (%) of dairy cows fed on different rations comprising 60% TMR and 40% oat hay from three harvest maturity stages are given in Table IV. Harvest maturity stage of oat didn't affect milk composition. The milk yield for the experimental rations from three maturity stages was 10.133, 13.966.33 and 10.966.67 kg/day, respectively. Milk yield was significantly (P<0.05) improved with ration II followed by III and ration I.

Table IV.- Milk yield and milk composition.

	Ration-I	Ration-II	Ration-III
Milk yield (kg/day)	10.133[c]	13.966[a]	10.966[b]
Milk composition (fat, %)	4.67	4.77	4.58
Total solids	7.34	7.30	7.43
Protein	2.59	2.72	2.67
Lactose	3.70	3.86	3.70

Milk yield values with different superscripts within same row are significantly different (P<0.05). For details, see Table II.

Milk yield throughout the experimental period increased. The results are coincided with the findings of Abeysekara (2003) who also reported higher milk yield with oat hay fed to dairy cows. However, in contrast, Kennelly *et al*. (1995) reported lower milk yield with oat hay. In mixed ration for feeding dairy animals, producers often use low-quality forages due to perception that forage nutrition is insignificant relative to the total diet offered. Our results are in line with Undersander and Moore (2008) who reported, higher milk yield from lactating dairy cows fed on high forage ratio in mixed diets.

In present study, composition of milk (milk fat, total solid, protein and milk lactose) was not significantly affected by the various stages of oat hay. Burgess *et al*. (1973) showed similar tendency of milk composition with oat hay. Our results are not in line with the findings of Khorasani *et al*. (1997) who reported the influence of oat hay on milk composition in dairy cows.

Table V.- Oat hay yield per plot on fresh and dry matter basis from different harvest maturity stages (n=5).

	Ration-I	Ration-II	Ration-III
Hay yield (kg)			
Fresh basis	6710[a]	6450[b]	5900[c]
DM basis	1114[c]	1856[b]	2242[a]
Dry matter (%)	16.17[c]	29.40[b]	38.12[a]

Values with different superscripts within same row are significantly different (P<0.05). For details, see Table II.

Dry matter yield

Dry matter yield of oat hay from different phases of crop growth was higher at boot stage followed by flower and dough stage (Table V). Our results of oat yield (DM basis) showed that appropriate period for harvesting oat crop is mainly early flower and soft dough. Similar findings were reported by Uzun (2010) and DAFF (2012). This could be related to most favorable climatic conditions for that harvest. Oat harvested for hay making at boot stage produced hay with lower nutritive value and less forage yield per acre than harvested at either early flower or soft dough stage. It appears that total nutrients resulted from oat hay are maximum at flowering stage. Maturity level at harvest mostly determines the yield and quality of forage. In oat, forage yield varies from 90 to 110% from the boot stage to the soft dough stage with decline crude protein drops and increase in fiber fraction (Werry, 1998).

CONCLUSION AND RECOMMENDATIONS

The stage of plant harvest maturity had significant impact on hay quality. As forage matured, fiber and lignin contents increased and also affected rate of digestion with reduced oat hay intake that led consequently to reduce animal production.

Ideal time for harvesting high quality hay is at flowering stage. Oat harvested at flowering stage for hay making resulted good dry matter yield with better quality. Hay prepared from flowering stage of oats resulted high nutritive value and maximum milk production from lactating Holstein Friesian cows with better milk composition.

For future study the effect of oat hay from various harvesting stages on *in vitro* and *in vivo* digestibility and intake under local environmental conditions should be investigated to increase meat production in small ruminants. The use of nitrogen fertilizer on harvesting area and its effect on dry matter yield at boot, flowering and dough stage should also be investigated.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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