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Research note: Effect of drying methods on the chemical composition of hay made from two desert grasses

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Abstract

Six methods of drying hay for dry season feeding were compared, including solar drying devices, electrical oven-type devices and traditional sun-air and shade drying. Traditional processes like shade drying and sun-air drying resulted in comparatively higher loss of nutrients, especially in terms of crude protein and carbohydrate level with 12–40% losses in crude protein concentration, 28–49% reduction in carbohydrate concentration and significant reduction in chlorophyll and carotenoid concentrations (72–91%). Solar dryers have been found to be more efficient with lower nutrient losses and their renewable nature and may be used for hay making especially in regions where fodder deficits occur in the dry season.

Introduction

The preservation and storage of surplus herbage as hay is a common practice in temperate and arid regions. However, during this process, the basic aim of producing high quality feed is often overlooked, so that the hay produced is nutritionally equivalent to poor quality crop residues. Nutritional quality of hay depends mainly on time of cutting or stage of maturity and process of drying (Sullivian 1973). Traditional processes of drying in the arid region of India include sun-air drying and shade drying. However, depending upon the temperature and the process used, drying causes losses mainly in water-soluble carbohydrates due to respiration and possible decomposition (Abdalla *et al.* 1988) and the Mailard reaction (Schnickels *et al.* 1976). This study examined the effects of different drying methods on chemical composition of hay made from desert grasses.

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Materials and methods

The grasses *Cenchrus ciliaris* and *Lasiurus sindicus* were harvested at the flowering stage from C.R. Farm, Jodhpur during August (rainfall 180 mm; minimum and maximum temperatures 25.5°C and 33.4°C, respectively) and were dried using the following devices:

- Solar dryer 'A', which is essentially a multi-purpose device (Pande *et al.* 1981). This unit has a glass cover fixed at 23° from horizontal on a wooden frame at the top of a cabinet with horizontal drying trays. Holes are provided at the sides of the bottom to induce fresh air and two chimneys are incorporated at the top of the rear sides for the exit of hot, moist air.
- Solar dryer 'B', also a solar cabinet dryer with chimney (Pande 1980) which has holes at the base for inducing fresh air with similar drying trays as in solar dryer 'A'.
- Oven, which is essentially an electrical system with thermostatically controlled temperature.
- Solar dryer cum solar water heater, a device which can be used both as a solar dryer and as a water heater (Pande and Thanvi 1991). This incorporates a galvanised iron tank to hold water and a wiremesh tray with two compartments to keep the material on an inclined plane. When used as a dryer, the water in the galvanised iron tank beneath the drying trays also gets heated during day time and this hot water keeps the dehydration process continuous, even during the night. Moreover, the

drying temperature is also regulated to lower limits even with higher levels of solar radiation.

In addition to the above, the conventional methods of sun-air and shade drying were also used. The treatments were therefore: Solar dryer 'A' (T1); Solar dryer 'B' (T2); Oven drying (T3); Solar dryer cum water heater lower compartment (T4); Solar dryer cum water heater upper compartment (T5); Sun drying (T6); and Shade drying (T7). In the case of *Lasiurus sindicus*, oven drying was performed at both 60°C and 80°C; only 80°C was used with *Cenchrus ciliaris*.

The temperatures inside the devices during the day time were found to vary from 30–60°C in solar dryers A and B, 32–57°C in solar dryer cum water heater (upper compartment) and 31–55°C (lower compartment). Temperatures in the oven were fixed at 60° C or 80°C. Average temperature during open sun drying was 34°C, and 20°C during shade drying.

The duration of drying was 16 h in solar dryers A and B, 14 h in solar dryer cum water heater, 8–10 h in the oven, 25 h in open sun drying and 32 h in shade drying. The chemical composition of fresh and dried grasses was estimated in terms of: crude protein (AOAC 1975) using Kjeltec 1000; total soluble sugars and starch (Yemn and Willis 1954); and chlorophyll and carotenoids (Robbelen 1957). The experimental data were analysed statistically using the two-way analysis of variance system (Snedecor and Cochran 1967).

Results and Discussion

The nutrient concentrations in fresh and dried samples of the grasses are shown in Tables 1(a) and 1(b) and the per cent loss of nutrients for both grasses in Table 2.

Losses of nutrients were quite substantial with most drying methods, although considerable variation in the extent of losses existed. Losses of crude protein ranged from 5.2–40.7% in *C. ciliaris* and 4.2–25.9% in *L. sindicus*. In both cases, the lowest losses occurred with grass dried in the lower compartment of the solar dryer cum water heater (maximum temperature 55°C). Hays made from *C. ciliaris* in the mechanical devices were generally of better quality (8.8–13.1% CP) than those made by conventional methods of sun (9.4% CP) and shade (8.2% CP) drying.

However, this pattern was not consistent with losses of other nutrients. Losses of soluble sugars varied from 12.9% to 49.2% in *C. ciliaris* and from 14.9% to 51.1% in *L. sindicus*. There was no consistency in the losses recorded with different drying methods. Similarly, losses of starch ranged from 14.3% to 37.5% and losses of

Table 1(a). Effect of drying methods on chemical composition (DM basis) of hays from *Cenchrus ciliaris*.

Type of dryer/ Method of drying	Crude protein	Total soluble sugars	Starch	Chlorophyll	Carotenoids
	(%)	(%)	(%)	(mg/g)	(mg/g)
Fresh sample	13.80	5.73	8.9	4.81	0.23
	(21.81)[1]	(13.81)	(17.36)	(12.66)	(2.56)
Solar dryer 'A'	12.14	4.21	5.56	1.8	0.14
	(20.36)	(11.83)	(13.69)	(7.71)	(1.81)
Solar dryer 'B'	8.8	4.99	6.58	1.28	0.08
	(17.26)	(12.92)	(14.89)	(6.55)	(1.81)
Oven drying at 80°C	10.36	4.13	7.44	2.34	0.22
	(18.81)	(11.68)	(15.79)	(8.72)	(2.56)
Solar dryer cum water heater- lower compartment	13.08	4.14	5.88	2.29	0.16
	(21.22)	(11.68)	(14.06)	(8.72)	(2.56)
Solar dryer cum water heater- upper compartment	11.24	3.86	5.72	1.64	0.12
	(19.55)	(11.39)	(13.81)	(7.27)	(1.81)
Sun drying	9.38	4.08	6.25	1.28	0.08
	(17.85)	(11.68)	(14.54)	(6.55)	(1.81)
Shade drying	8.18	2.91	5.81	1.31	0.01
	(16.64)	(9.80)	(13.94)	(6.55)	(—)
C.D.[2] ($P<0.01$)	1.383	0.615	0.866	0.71	—
C.D. ($P<0.05$)	0.935	0.416	0.585	0.48	—

[1] Values in parenthesis show angular-transformed values.
[2] Critical difference.

Table 1(b). Effect of drying on chemical composition (DM basis) of hays from *Lasiurus sindicus*.

Type of dryer/Method of drying	Crude protein	Total soluble sugars	Starch	Chlorophyll	Carotenoids
	(%)	(%)	(%)	(mg/g)	(mg/g)
Fresh sample	9.15	4.23	9.25	2.58	0.071
	(17.66)[1]	(11.83)	(17.76)	(9.28)	(1.81)
Solar dryer 'A'	7.10	2.07	6.42	0.92	0.06
	(15.45)	(8.33)	(14.77)	(5.44)	(1.81)
Solar dryer 'B'	6.78	2.88	7.27	0.85	0.048
	(15.12)	(9.80)	(15.56)	(5.44)	(1.81)
Oven drying at 60ºC	7.31	2.89	7.72	1.46	na[3]
	(15.68)	(9.80)	(16.11)	(7.03)	
Oven drying at 80^{0}C	8.20	2.90	7.93	1.30	na
	(16.64)	(9.80)	(16.32)	(6.55)	
Solar dryer cum water heater -lower compartment	8.77	3.46	7.65	1.43	na
	(17.26)	(10.78)	(16.11)	(6.80)	
Solar dryer cum water heater -upper compartment	7.76	3.60	7.44	1.20	na
	(16.22)	(10.94)	(15.79)	(6.29)	
Sun drying	7.33	2.41	7.44	1.22	na
	(15.68)	(8.91)	(15.79)	(6.55)	
Shade drying	6.89	2.53	7.27	1.12	na
	(15.23)	(9.10)	(15.56)	(6.02)	
C.D.[2] ($P<0.01$)	0.539	0.568	0.725	0.390	—
C.D. ($P<0.05$)	0.370	0.390	0.498	0.268	—

[1] Values in parenthesis show angular-transformed values.
[2] Critical difference.
[3] Negligible amount.

Table 2. Percent loss of nutrients during the drying process with different drying methods.

Cenchrus ciliaris	T1[1]	T2	T3(a)	T4	T5	T6	T7
Crude protein	12.0	36.2	24.9	5.2	18.6	32.0	40.7
Total soluble sugars	26.5	12.9	27.9	27.7	32.6	28.8	49.2
Starch	37.5	26.1	16.4	33.9	35.7	29.8	34.7
Chlorophyll	62.6	73.4	51.4	52.4	65.9	73.4	72.8
Carotenoids	39.1	65.2	4.3	30.4	47.8	65.2	95.7

Lasiurus sindicus	T1[1]	T2	T3	T3(a)	T4	T5	T6	T7
Crude protein	22.4	25.9	20.1	10.4	4.2	15.2	19.9	24.7
Total soluble sugars	51.1	31.2	31.7	31.4	18.2	14.9	43.0	40.2
Starch	30.6	21.4	16.5	14.3	17.3	19.6	19.6	21.4
Chlorophyll	64.3	67.1	43.4	49.6	44.6	53.5	52.7	56.6
Carotenoids	15.5	32.4	na[2]	na	na	na	na	na

[1] T1 = solar dryer A; T2 = solar dryer B; T3 = oven drying at 60°C; T3(a) Oven drying at 80°C; T4 = solar dryer cum water heater-lower compartment; T5 = solar dryer cum water heater-upper compartment; T6 = sun-air drying; T7 = shade drying.
[2] Negligible amount.

chlorophyll from 43.4% to 73.4%. There was no consistency across treatments.

Nutrient losses are to be expected during the drying process. Earlier studies showed that passing heated air at 80–150°C over baled alfalfa reduced sugar and amino acid concentrations (Hathout 1961). It is normally assumed that the hydrolytic and respiratory enzymes present in the living cell continue to function until some lethal condition intervenes. Respiration is accompanied by the loss of more soluble carbohydrates. A temperature around 40°C provides suitable conditions for enzyme activity and thus increases losses, whereas a temperature above 45°C halts respiration sooner. The generally poorer quality of hays made by sun or shade drying may be a function of the lower drying temperatures employed. Sun-air drying exposes material to ultraviolet radiation which could cause the browning or Mailard effect (Dzowela *et al.*

1995). Air drying under a thatched shade avoids direct ultraviolet radiation but losses of carbohydrates and other nutrients are bound to occur because temperatures are lower and drying time is prolonged.

Among the solar devices used, the solar dryer cum water heater gave best results. With solar dryers A and B, there is no provision for heat storage so drying takes place only during the day. In comparison, the drying continues during the night through the heated water in the solar dryer cum water heater. The increased rate of drying reduced the overall drying period by 2 h. In addition, the maximum temperature inside the dryer cum water heater is 3–5°C lower than that in solar dryers A and B, which might also have affected hay quality.

To make good hay, moisture content of herbage must be reduced to a point low enough to allow storage without marked nutritional changes. None of the drying methods used in our study could achieve the necessary reduction without significant nutrient losses. However, CP and carbohydrate concentrations of the hays were significantly higher than those of fibrous crop residues including dry grasses harvested at maturity and normally fed to ruminants in the region in the absence of hay making. The hays made from *C. ciliaris* would support low levels of production in ruminants, whereas those made from *L. sindicus* would provide little better than maintenance.

While sun-air drying is practicable and commonly used on farms in smallholder and medium-scale farming systems in the arid region, associated losses shown in this study are significant. Methods using solar and electrical devices can be useful for drying fodder. However, operating costs for electric ovens can be substantial. On the other hand, operating costs of solar dryers are low. Farmers may opt to use solar dryers for hay making because nutrient losses are reduced, drying is faster than with open sun drying, a renewable energy source is used, which is freely available and is plentiful in arid regions, and operating costs are minimal. The availability of capital to purchase the drying devices initially may also be a serious impediment to the use of this technology.

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