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STUDY ON SOME THERMAL PARAMETERS AFFECTING PRODUCTION OF HAY BALES

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ABSTRACT: **The experiments were carried out during the season of 2005 / 2006 at village of Taha El-Marg Diarb Negm Sharkia Governorate to study the effect of operational conditions on the production of clover hay bales.**

Two different drying methods were used to dry clover (artificial drying using a developed dryer and direct sun drying). Under artificial drying many treatments were studied: two initial bale moisture contents of (65 and 75% wb), three flow rates of (28, 36 and 44m^3min^{-1} and three bale sizes of (10, 20 and 30×38×46 cm).

Evaluation of the studied treatments was executed taking into consideration chemical analysis, physical analysis, and digestibility.

The obtained results from the present investigation recorded high dried bale quality in the case of:

1. **Using artificial drying by the developed dryer.**
2. **Begin drying at a initial bale moisture content of 65%.**
3. **Using small bale size of 10×38×46 cm.**
4. **Adjusting air flow rate at 28 m^3min^{-1}.**

Key words: Drying methods, moisture content, air flow rate and bale size.

INTRODUCTION

The commodity in Egypt for berseem drying is direct sun drying on the ground in the field. During this process the plants losses a high percentage of its leave, which contains the valuable nutrients. It was surprising that the questionnaire showed a need to develop this process beside the need for developing other drying processes (Ali *et al.*, 1980). Therefore, using heated air was led to minimize nutrient losses of leaves (Shoukry *et al.*, 1989).

Hay quality is affected by such factors as maturity at harvest, soil fertility, nutritional status of plant, available moisture during the growing season, season of the year, ratio of leaves to stems, stem size, weed control, foreign matter, harvesting and weather at harvest and storage. The most important is stage of maturity as age of the plant at harvest.

El-Sahrigi *et al.* (1970), studied the effect of air temperature, air velocities and try loading on the drying rate of Egyptian onion verities. They found that the higher temperature and air velocity the greater the drying rate.

Wilkinson (1981), stated that the drying process is usually done in the field. The rate of drying is dependent on weather conditions, temperature, humidity, soil moisture, solar radiation and wind speed. The drying behavior of the forage is affected by plant species, stage of growth, leaf-to-stem ratio and the structure and volume of the swath or windrow. The rate of moisture loss follows an exponential pattern so that a drop in moisture from 80% at cutting to 30%, may take as much time as dropping from 30% to 20%.

UK, Electricity Council, Farm-Electric Centre (1985), described the electrical methods of hay drying for baled material and chopped material; equipment in use may be fans (axial, centrifugal), heaters, and measuring devices this methods given a quality hay.

Tchiengue and Kaptouom (1986), mentioned that the drying rate can be expressed by one of three terms: rate of water loss as a function of time of residual dry matter and rate of mass loss as a function of time. The expressions and the units in which the drying rate often are representing by any one of three terms: removed water per unit time, per unit area of the drying surface or per unit volume of the circulating air, and decrease of moisture content per unit time.

House and Stone (1988), found that the amount of airflow required depends on the initial hay moisture content and the grass-legume mixture of the forage. The following airflow rates can be used as a guideline when the moisture content were lower than 25% , 25-30% and 30-35% the air flow rates were 80, 160, and 260 (L/s/tonne) respectively.

Shourky (1990), found that the crude protein, crude fiber, ether extract, nitrogen free extract, and Ash were 11.9, 26.80, 2.50, 37.20 and 11.90, respectively for 1^{rd} cut, under solar dehydration drying.

Atia (1992), used some drying systems for drying clover such as: sun drying (SD), artificial drying by oven (AD), solar dryers systems (SD1, SD2 and SD3). He found that the drying system SD have low values of crude protein, ether extract, chlorophyll A, B and carotenoids but have high values of dry matter, crude fiber, and nitrogen free extract for clover compared with to other systems.

Paine and Paine (1992), classified the methods of drying into groups. The first is sun drying or air drying. This traditional method of drying is limited to countries with a hot climate and a dry atmosphere, and to certain products, such as raisins, figs, and prunes, which are spread out on trays and turned over during drying. The second method is the mechanical drying. Methods of mechanical drying vary according to the materials being handled, but usually involve heated air (with controlled low relative humidity) or steam being passed over the product be dried.

The objectives of this research are:

1. Development of a small unit for hay drying.
2. Optimization of some parameters affecting the performance of the developed unit.
3. Evaluate the developed unit from the economic point of view.

MATERIALS AND METHODS

The experimental work was carried out during the season of 2005 / 2006 at village of Taha El-Marg Diarb Negm Sharkia Governorate, to study the effect of some thermal parameters on the production of clover hay bales.

Materials

The Used Product

Berseem was used as Egyptian clover to be dried.

The Developed Dryer

The developed dryer is consisted of drying chamber, shelves, two fans, two heaters, thermostats and thermocouples. (Fig.1).

The Drying Chambers

The drying chamber was built of clay stone. Its dimensions are 180×230×180 cm.

Shelves

Clover bales were put on shelves inside the drying chamber.

Fans

Two fans were used to remove moisture outside the drying chamber.

Heaters

A group of heaters were used in order to provide heat inside the drying chamber.

Thermostats

The thermostats were functioned to adjust the temperature degree inside the dryer in the range of 70°.

Thermocouples

The thermocouples were used to measure the air temperatures inside and outside the dryer.

Methods

Two drying systems were used for drying clover:

Direct Sun Drying

Clover was collected and then thrown in the field for 7-10 days to be dried by the sun after this period.

Artificially Drying

Clover was collected and then thrown in the field for 1-3 days to reduce the moisture content to a range between 75-65%. Then it was baled. Bales were put in a developed dryer to reduce drying period and reach the optimum level of moisture content (ranged between 15-20%) then stored.

The developed dryer was examined as function of change in bale size, bale moisture content and air flow rate.

Bales size

Three bale sizes were studied as follows: 10, 20 and 30×38 ×46 cm.

Bale moisture content

The three bale sizes were put in the developed dryer at two initial different moisture contents of 75% and 65%.

Air flow rate of fans

Three air flow rates were used as follows: 28, 36 and 44 $m^3 min^{-1}$.

Evaluation of the above mentioned treatments was carried out taking into consideration chemical analysis, physical analysis,

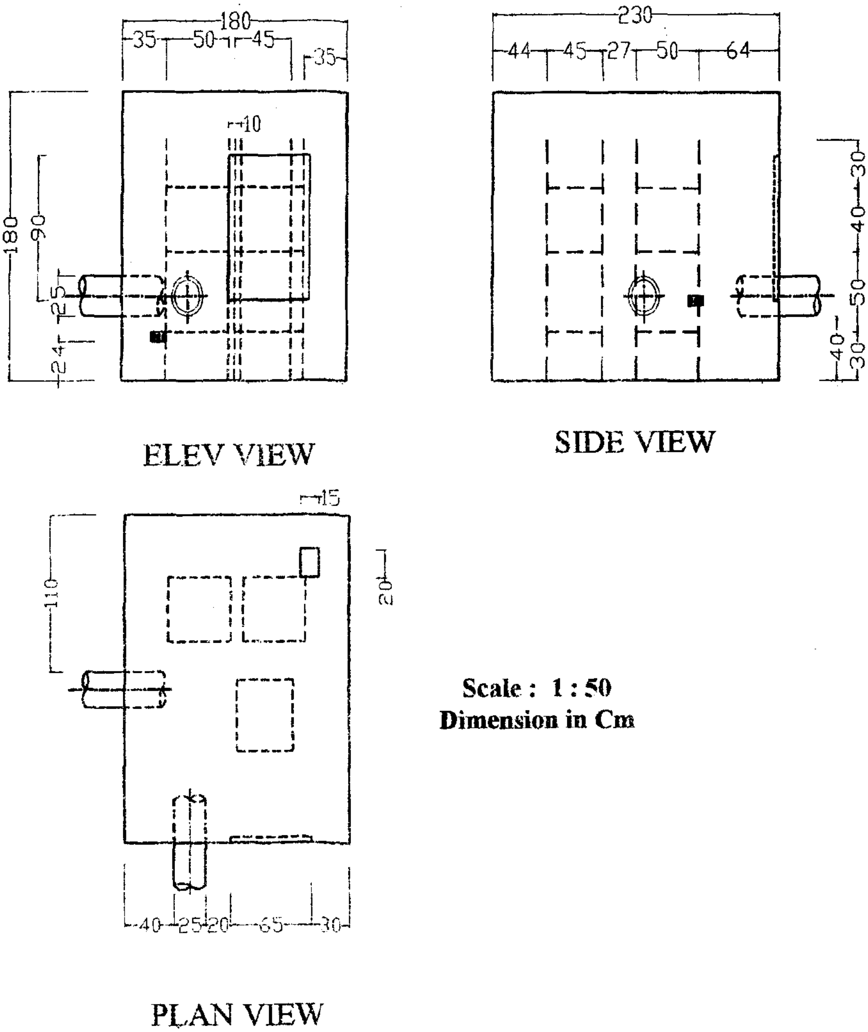

Fig. 1. Elevation, plan and side view of the developed dryer

drying period, temperature, moisture content, digestibility evaluation and production cost.

RESULTS AND DISCUSSION

Effect of Some Parameters on Chemical Characteristics of Dried Clover

The chemical characteristics for the dried clover were significantly affected by drying method, air flow rate and bale size.

Effect of drying method on chemical characteristics

Results show that the chemical characteristics of dried clover are greatly affected drying method. (Fig.2).

Concerning dry matter (DM), the obtained results show that dry matter value was 83.63% under sun drying. While dry matter values were 82.33 and 84.31% under artificial drying at constant air flow rate of 28 m^3.min-1 and constant bale size of 10×38×46 cm and under 75 and 65% initial bale moisture contents, respectively.

Relating to crude protein (CP), the obtained data show that crude protein value was 11.19% under sun drying. While crude protein values were 16.77 and 18.82% with artificial drying under the same previous conditions.

Considering ether extract (EE), the obtained results show that ether extract value was 1.67% under sun drying. While ether extract values were 2.39 and 1.58% with artificial drying under the same previous conditions.

With regard to crude fiber (CF), the obtained data show that crude fiber value was 27.77% under sun drying. While crude fiber values were 22.58 and 20.64% with artificial drying under the same previous conditions.

Regarding nitrogen free extract (NFE), the obtained results show that nitrogen free extract value was 44.98% under sun drying.

While nitrogen free extract values were 47.74 and 48.03% with artificial drying under the same previous conditions.

Ash, the obtained data show that the ash value was 14.9% under sun drying. While the ash values were 10.52 and 10.93% with artificial drying under the same previous conditions.

Results also show that highest values of crude protein, ether extract and nitrogen free extract were found under artificial drying, while, vice versa was noticed with sun drying.

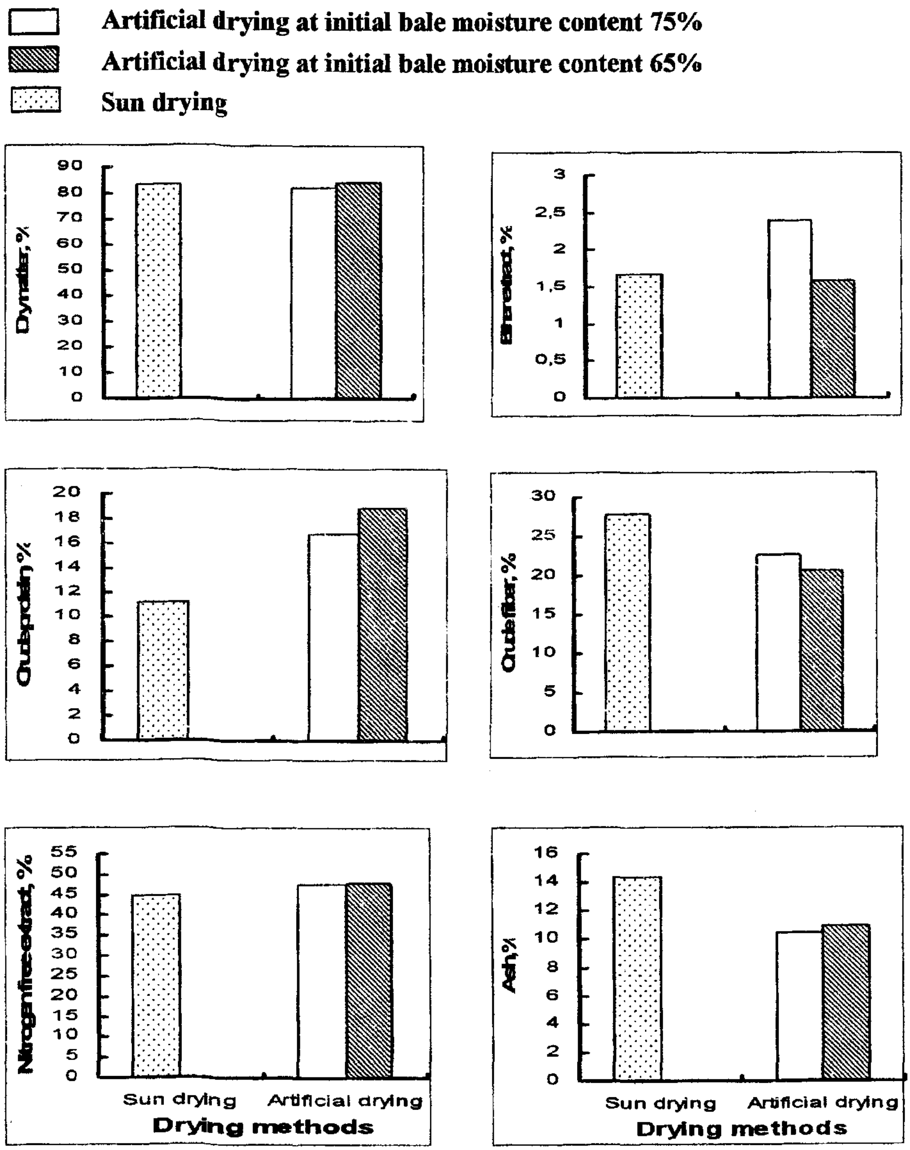

Fig. 2. Effect of drying methods on some chemical characteristics of clover dried bales under two different initial bale moisture contents. (Air flow rate=28m^{3}min^{-1}, bale size= 10×38×46cm)

These results can be explained as the clover plants loss high percentage of their leaves which contains the valuable nutrients under sun drying.

Effect of air flow rate on chemical characteristics

Results show that the chemical characteristics of dried clover are insignificantly affected by air flow rate. (Fig. 3).

Concerning dry matter (DM), the obtained results show that dry matter values were 82.33, 82.77 and 82.59% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content, respectively. While dry matter values were 84.31, 84.28 and 85.29% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content with artificial drying and at constant bale size of 10×38×46cm, respectively.

Relating to crude protein (CP), the obtained data show that crude protein values were 16.77, 14.84 and 17.64% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While crude protein values were 18.82, 14.99 and 13.54% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

Considering ether extract (EE), the obtained results show that ether extract values were 2.39, 2.0 and 1.76% at air flow rates of 28, 36 and 44 m^3min^{-1} under 75% initial bale moisture content. While ether extract values were 1.58, 2.24 and 1.64% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

With regard to crude fiber (CF), the obtained data show that crude fiber values were 22.58, 23.65 and 26.68% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While crude fiber values were 20.64, 22.40 and 25.91% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

Regarding nitrogen free extract (NFE), the obtained results show that nitrogen free extract values were 47.74, 47.81 and 41.96% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While nitrogen free extract values were 48.03, 49.53 and 48.13% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

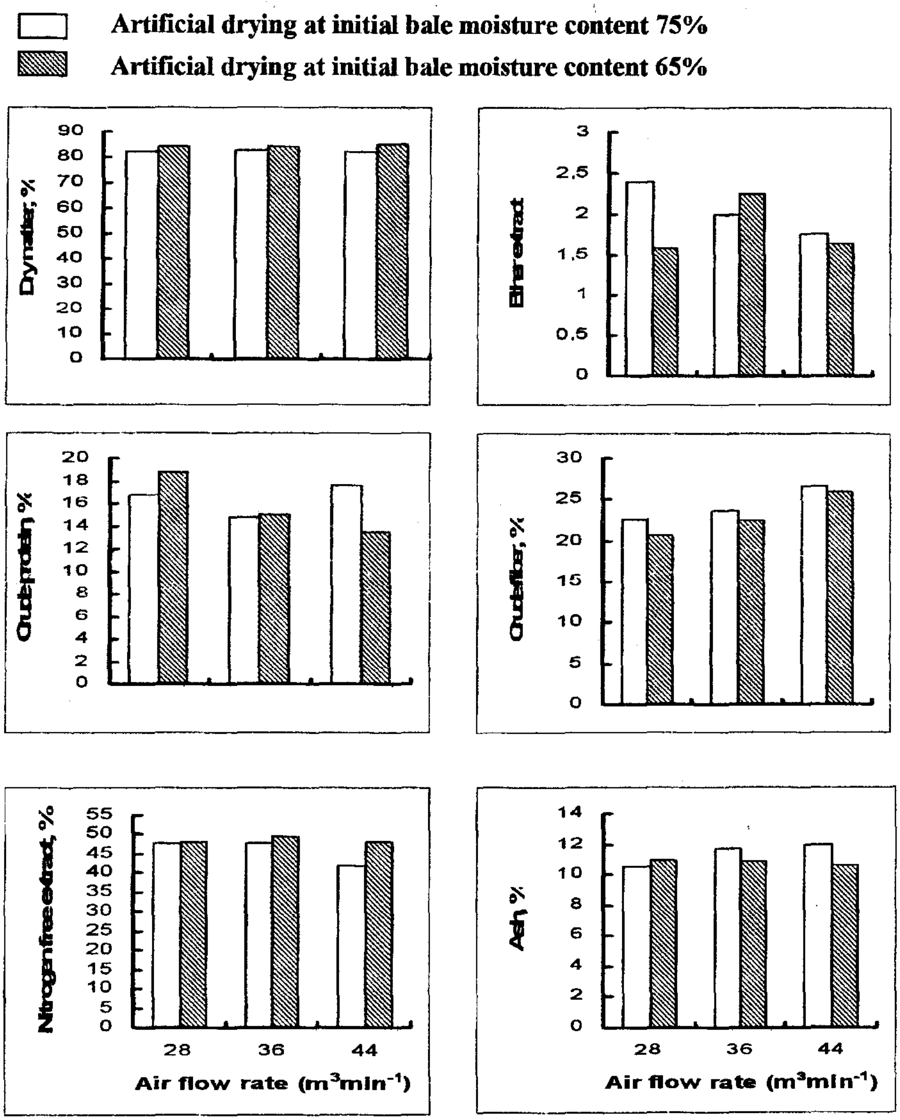

Fig. 3. Effect of air flow rate on some chemical characteristics of clover dried bales under two different initial bale moisture contents. (Artificial drying, bale size=10×38×46cm)

As to ash, the obtained data show that ash values were 10.52, 11.70 and 11.96% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While ash values were 10.93, 10.84 and 10.59% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

The obtained results show that bale at 75% initial bale moisture content achieve low value of crude protein, dry matter and nitrogen free extract comparing with initial bale moisture content of 65%.

Air flow rate has insignificant effect on chemical characteristics because its effect is only significant on drying period.

Effect of bale size on chemical characteristics

Results show that the chemical characteristics of dried clover are greatly affected by bale size. (Fig. 4).

Concerning dry matter (DM), the obtained results show that dry matter value was 82.33% with bale size of 10×38×46 cm, under 75% initial bale moisture content. While dry matter values were 84.31, 82.98 and 81.91% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content with artificial drying and constant air flow rate of 28m^3min^{-1}.

Relating to crude protein (CP), the obtained data show that crude protein value was 16.77% with bale size of 10×38×46 cm under 75% initial bale moisture content. While crude protein values were 18.82, 17.31 and 15.66% with bale sizes of 10×38×46, 20 × 38 × 46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

Considering ether extract (EE), results obtained show that ether extract value was 2.39% with bale size of 10×38×46 cm under 75% initial bale moisture content. While ether extract values were 1.58, 2.08 and 2.43% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

With regard to crude fiber (CF), the obtained data show that crude fiber value was 22.58% with bale size of 10×38×46 cm under 75% initial bale moisture content. While crude fiber values were 20.64, 21.41 and 21.76% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

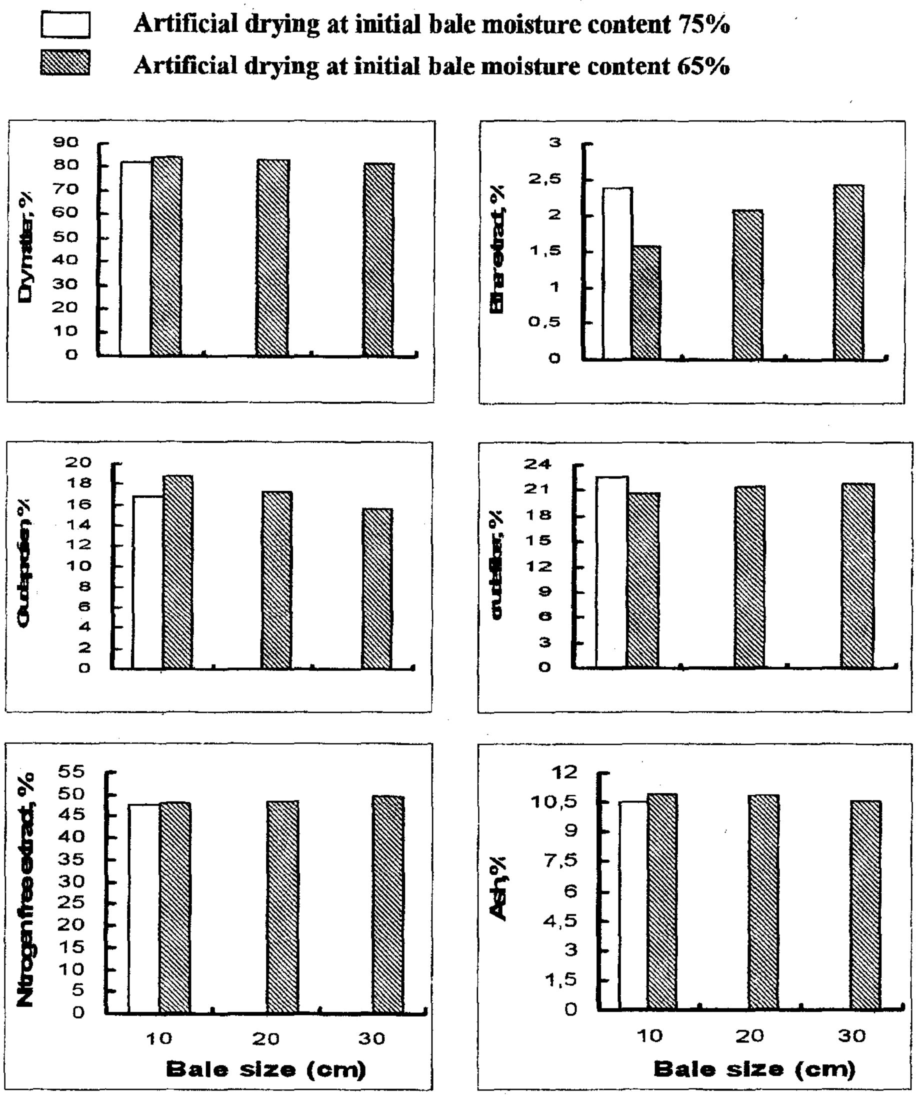

Fig. 4. Effect of bale size on some chemical characteristics of clover dried bales under two different initial bale moisture content. (Artificial drying, air flow rate=28m^{3}min^{-1})

Regarding nitrogen free extract (NFE), the obtained results show that nitrogen free extract value was 47.74% with bale size of 10×38×46 cm under 75% initial bale moisture content. While nitrogen free extract values were 48.03, 48.31 and 49.55% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

As to ash, the obtained data show that ash value was 10.52% with bale size of 10×38×46 cm under 75% initial bale moisture content. While ash values were 10.93, 10.89 and 10.60% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

High initial bale moisture content of 75% tends to decrease dry matter, crude protein nitrogen free extract and ash comparing with initial bale moisture content of 65% during artificial drying, because at high initial bale moisture content drying period is not enough to extract water and the poison of bales is occurred.

The two bale sizes of 20×38×46 and 30×38×46 cm at initial moisture content of 75% contains high percent of crude protein due to its fermentation for this reason.

Effect of Some Parameters on Physical Characteristics of Dried Clover

The physical characteristics for dried clover were significantly affected by drying method, air flow rate and bale size.

Effect of drying method on physical characteristics

Results show that the physical characteristics of dried clover are greatly affected by drying method. (Fig.5).

Concerning carotenoids, the obtained results show that carotenoids value was 0.28 $mg.g^{-1}$ under sun drying. While carotenoids values were 0.63 and 0.94 $mg.g^{-1}$ under artificial drying at constant air flow rate of 28 $m^3.min^{-1}$ and constant bale size of 10×38×46 cm and under 75 and 65% initial bale moisture contents respectively.

Relating to chlorophyll A, the obtained data show that chlorophyll A value was 1.41 $mg.g^{-1}$ under sun drying. While chlorophyll A values were 2.23 and 3.78 $mg.g^{-1}$ with artificial drying under the same previous conditions.

Considering chlorophyll B, the obtained results show that chlorophyll B value was 1.06 $mg.g^{-1}$ under sun drying. While chlorophyll B values were 2.5 and 4.46 $mg.g^{-1}$ with artificial drying under the same previous conditions.

Results show that highest values of carotenoids, chlorophyll A and chlorophyll B were found under artificial drying, while the vice versa was noticed with the use of sun drying.

These results can be explained as the clover plants lose high percentage of their leaves which contains the valuable nutrients under sun drying.

Effect of air flow rate on physical characteristic

Results show that the physical characteristics of dried clover are greatly affected by air flow rate. (Fig. 6)

With regard to carotenoids, the obtained data show that carotenoids values were 0.63, 0.58 and 0.49 $mg.g^{-1}$ at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While carotenoids values were 0.94, 0.77 and 0.68 $mg.g^{-1}$ at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content with artificial drying and constant bale size of 10×38×46 cm.

Regarding chlorophyll A, the obtained results show that chlorophyll A values were 2.23, 2.12 and 1.56 $mg.g^{-1}$ at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While chlorophyll A values were 3.78, 3.01 and 2.37 $mg.g^{-1}$ at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

As to chlorophyll B, the obtained data show that chlorophyll B values were 2.5, 2.02 and 1.87 $mg.g^{-1}$ at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While chlorophyll B values were 4.46, 2.25 and 1.84 $mg.g^{-1}$ at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

The obtained results show that bale at 65% initial bale moisture content achieve high value of carotenoids, chlorophyll A and chlorophyll B comparing with initial bale moisture content of 75%.

Air flow rate has a significant effect on physical characteristics, when the air flow rate increases the values of carotenoids, chlorophyll A and chlorophyll B decrease.

Effect of bale size on physical characteristic

Results show that the physical characteristics of dried hay are greatly affected by bale size. (Fig. 7).

Relating to carotenoids, data obtained show that carotenoids value was 0.63 $mg.g^{-1}$, with bale size of 10×38×46 cm under 75% initial bale moisture content. While carotenoids values were 0.94, 0.76 and 0.58 $mg.g^{-1}$, with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content with artificial drying and constant air flow rate of $28m^3min^{-1}$.

As to chlorophyll A, the obtained data show that chlorophyll A value was 2.23 $mg.g^{-1}$, with bale size of 10×38×46 cm under 75% initial bale moisture content. While chlorophyll A values were 3.78, 3.07 and 2.84 $mg.g^{-1}$, with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

Considering chlorophyll B, the obtained results show that chlorophyll B value was 2.5 $mg.g^{-1}$, with bale size of 10×38×46 cm under 75% initial bale moisture content. While chlorophyll B values were 4.46, 2.52 and 1.73 $mg.g^{-1}$, with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

High initial bale moisture content of 75% tends to decrease carotenoids, chlorophyll A and chlorophyll B comparing with initial bale moisture content of 65% during artificial drying.

Bale size has a great effect on physical characteristics, when the bale sizes increase the values of carotenoids, chlorophyll A and chlorophyll B decrease.

The two bale sizes of 20×38×46 and 30×38×46 cm at initial moisture content of 75% contains low value of physical characteristics due to its fermentation.

Effect of some parameters on *in situ* of dried clover

The *in situ* for dried clover were significantly affected by drying method, air flow rate and bale size.

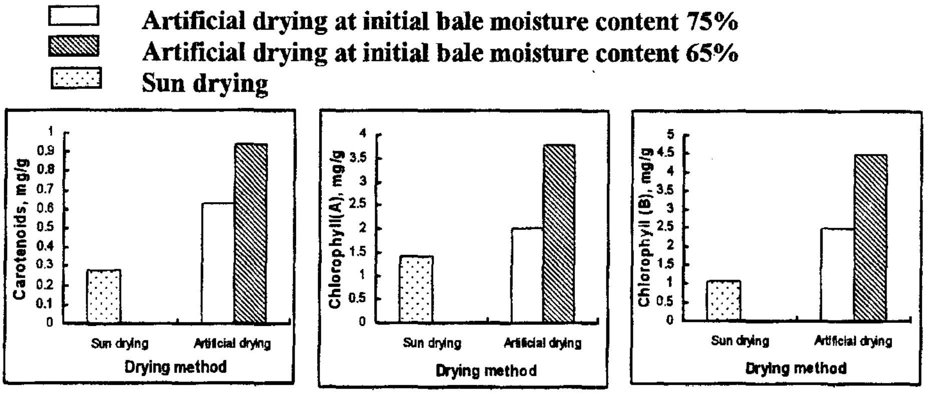

Fig. 5. Effect of drying methods on some physical characteristics of clover dried bales under two different initial bale moisture contents. (Air flow rate=28$m^3 min^{-1}$, bale size=10×38×46cm)

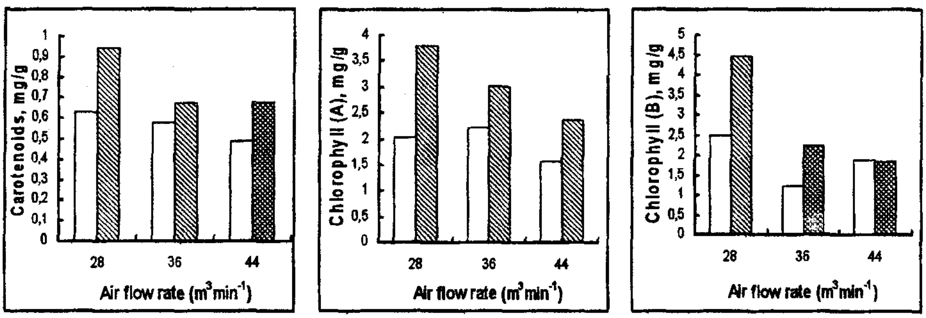

Fig. 6. Effect of air flow rate on some physical characteristics of clover dried bales under two different initial bale moisture contents. (Artificial drying, bale size=10×38×46cm)

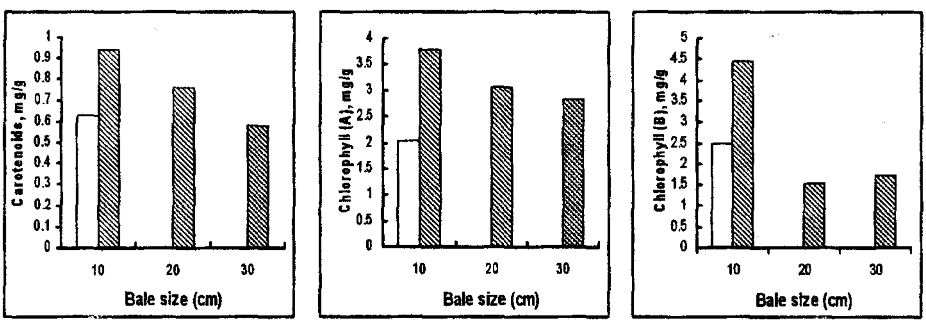

Fig. 7. Effect of bale size on some physical characteristics of clover dried bales under two different initial bale moisture contents. (Artificial drying, air flow rate=28$m^3 min^{-1}$)

Effect of drying method on *in situ* of dried clover

Results show that the *in situ* of dried clover are greatly affected by drying method. (Fig.8).

Concerning *in situ* dry matter disappearance (ISDMD), the obtained results show that in situ dry matter disappearance value was 47.29% under sun drying. While *in situ* dry matter disappearance values were 60.74 and 55.45% under artificial drying at constant air flow rate of 28 m^3min^{-1} and constant bale size of 10×38×46 cm and under 75 and 65% initial bale moisture contents respectively.

Relating to *in situ* organic matter disappearance (ISOMD), the obtained data show that *in* situ organic matter disappearance value was 44.21% under sun drying. While *in situ* organic matter disappearance values were 57.59 and 53.24% with artificial drying under the same previous conditions.

Results show that highest values of *in situ* dry matter disappearance and *in situ* organic matter disappearance were found under artificial drying, while the vice versa was noticed with the use of sun drying.

These results can be explained as the clover plants lose high percentage of their leaves which contains the valuable nutrients under sun drying.

Effect of air flow rate on *in situ* of dried clover

Results show that the *in situ* of dried clover are greatly affected by air flow rate (Fig. 9)

With regard to *in situ* dry matter disappearance (ISDMD), the obtained data show that *in situ* dry matter disappearance values were 60.64, 62.52 and 63.10% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While *in situ* dry matter disappearance values were 55.45, 58.81 and 58.86% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 65% initial bale moisture content with artificial drying and constant bale size of 10×38×46 cm.

As to *in situ* organic matter disappearance (ISOMD), the obtained results show that *in situ* organic matter disappearance values were 57.59, 58.27 and 59.76% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While *in situ* organic matter disappearance values were 53.24, 55.56 and 56.96% at air flow rates of 28, 36 and 44m^3min^{-1}, under 65% initial bale moisture content under the same previous conditions.

The obtained results show that bale at 65% initial bale moisture content achieve low value of *in situ* dry matter disappearance and *in situ* organic matter disappearance comparing with initial bale moisture content of 75%.

Air flow rate has effect on *in situ*, the values of *in situ* dry matter disappearance and *in situ* organic matter disappearance increase when the air flow rate increases.

Effect of bale size on *in situ* of dried clover

Results show that the *in situ* of dried hay are greatly affected by bale size. (Fig. 10).

Regarding *in situ* dry matter disappearance (ISDMD), the obtained data show that *in situ* dry matter disappearance value was 60.74% with bale size of 10×38×46 cm under 75% initial bale moisture content. While *in situ* dry matter disappearance values were 55.45, 57.95 and 59.02% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content with artificial drying and at constant air flow rate of 28 $m^3 min^{-1}$.

Considering *in situ* organic matter disappearance (ISOMD), the obtained results show that *in situ* organic matter disappearance value was 57.59% with bale size of 10×38×46 cm under 75% initial bale moisture content. While *in situ* organic matter disappearance values were 53.24, 54.16 and 56.49% with bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

High initial bale moisture content of 75% tends to decrease *in situ* dry matter disappearance and *in situ* organic matter disappearance comparing with initial bale moisture content of 65% during artificial drying.

Bale size has effect on in situ, when the bale size increases the values of in situ dry matter disappearance and in situ organic matter disappearance increase.

The two bale sizes of 20×38×46 and 30×38×46 cm at initial moisture content of 75% contains low percent of *in situ* dry matter disappearance and *in* situ organic matter disappearance due to its fermentation.

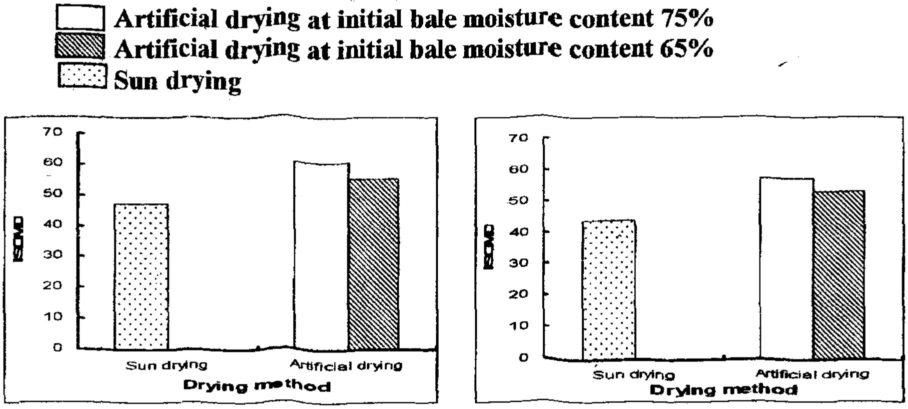

Fig. 8. Effect of drying methods on *in situ* of clover dried bales under two different initial bale moisture contents. (Air flow rate=28m^3min^{-1}, bale size=10×38×46 cm)

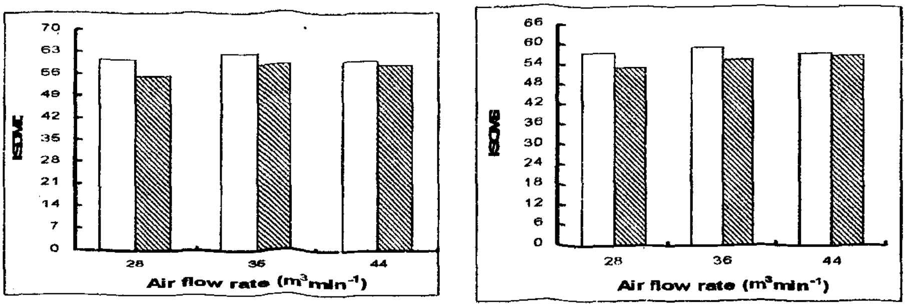

Fig. 9. Effect of air flow rate on *in situ* of clover dried bales under two different initial bale moisture content. (Artificial drying, bale size=10×38×46cm)

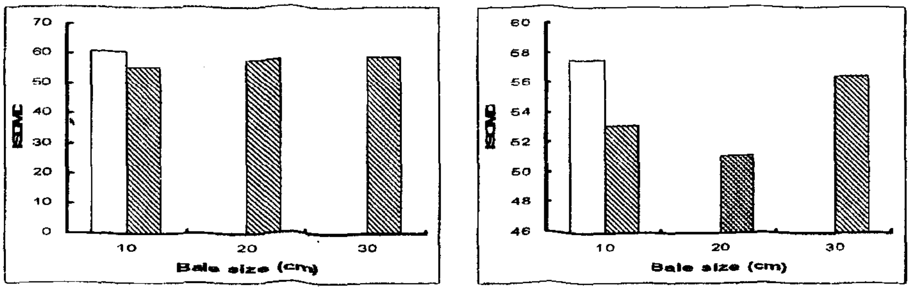

Fig. 10. Effect of bale size on *in situ* of clover dried bales under two different initial bale moisture content

(Artificial drying, air flow rate=28m^3min^{-1})

Effect of Some Parameters on Drying Time and Final Bale Moisture Content of Dried Clover

The drying time and final bale moisture content for clover were significant affected by drying method, air flow rate and bale size.

Effect of drying method on drying time and final bale moisture content

Results show that the drying time and final bale moisture content of dried clover are greatly affected by drying method. (Fig. 11).

Relating to drying time, the obtained data show that drying time value was 312 hr under sun drying. While drying time values were 6 and 4 hr under artificial drying at constant air flow rate of 28 $m^3.min^{-1}$ and constant bale size of 10×38×46 cm and under 75 and 65% initial bale moisture contents respectively.

Concerning final bale moisture content, the obtained results show that final bale moisture content value was 16.37% under sun drying. While final bale moisture content values were 17.67 and 15.69% with artificial drying under the same previous conditions.

Results show that maximum values of drying time was found under sun drying, while the vice versa was noticed with the use of artificial drying.

These results can be attributed to the high temperature that was used to drying by artificial drying (about 70°) but by sun drying drying temperature depends on the surrounding climate.

Effect of air flow rate on drying time and final bale moisture content

Results show that the drying time and final bale moisture content dried clover are greatly affected by air flow rate (Fig. 12)

With regard to drying time, the obtained data show that drying time values were 6, 5 and 4 hr at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content. While drying time values were 4, 3 and 2.5 hr at air flow rates of 28, 36 and 44m^3min^{-1}, under 65% initial bale moisture content with constant artificial drying and at constant bale size of 10×38×46 cm. While final bale moisture content values were 15.59, 15.72 and 14.71% at air flow rates of 28, 36 and 44 m^3min^1, under 65% initial bale moisture content under the same previous conditions.

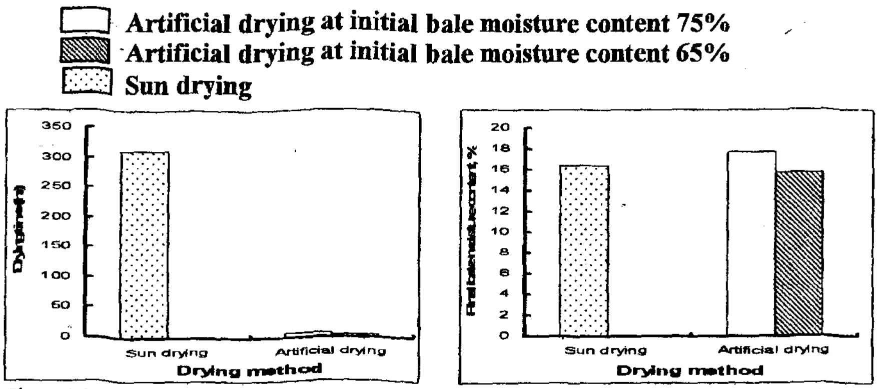

Fig. 11. Effect of drying methods on drying time and final bale moisture content of clover dried bales under two different initial bale moisture contents. (Air flow rate=28m^{3}min^{-1}, bale size=10×38×46 cm)

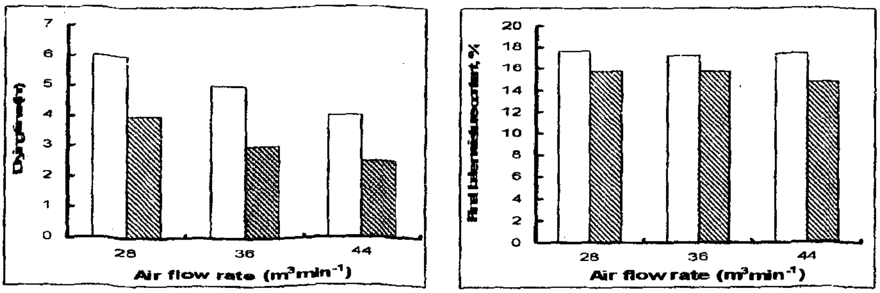

Fig. 12. Effect of air flow rate drying time and final bale moisture content of clover dried bales under two different initial bale moisture content.(Artificial drying, bale size=10×38×46cm)

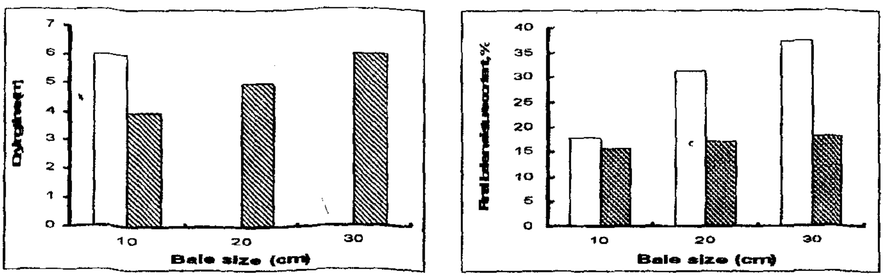

Fig. 13. Effect of bale size on drying time and final bale moisture content of clover dried bales under two different initial bale moisture content. (Artificial drying, air flow rate=28m^{3}min^{-1})

As to final bale moisture content, the obtained data show that final bale moisture content values were 17.67, 17.23 and 17.41% at air flow rates of 28, 36 and 44 m^3min^{-1}, under 75% initial bale moisture content.

The obtained results show that bale at 75% initial bale moisture content achieve high value of drying time comparing with initial bale moisture content of 65%.

Air flow rate has effect on drying time, when the air flow rate increases the values of drying time decrease.

Effect of bale size on drying time and final bale moisture content

Results show that the drying time and final bale moisture content of dried hay is greatly affected by bale size. (Fig. 13).

Regarding drying time, the obtained data show that drying time value was 6 at bale size of 10×38×46 cm under 75% initial bale moisture content. While drying time values were 4, 5 and 6 hr at bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content with artificial drying and at constant air flow rate of 28m^3min^{-1}.

Considering final bale moisture content, the obtained results show that final bale moisture content value was 17.67% at bale size of 10×38×46 cm under 75% initial bale moisture content. While final bale moisture content values were 15.69, 17.02 and 18.09% at bale sizes of 10×38×46, 20×38×46 and 30×38×46 cm under 65% initial bale moisture content under the same previous conditions.

High initial bale moisture content of 75% tends to increase drying time comparing with initial bale moisture content of 65% during artificial drying.

Bale size has effect on drying time, when the bale size increase the drying time increase.

The two bale sizes of 20×38×46 and 30×38×46 cm at initial moisture content of 75% contains high percent of moisture content that tends to bale fermentation.

Drying Cost

Results show that the drying costs of dried clover are greatly affected by drying method.

Concerning drying cost, the obtained results show that drying cost value was 0 L.E./kg under sun drying. While drying cost values were 0.39 and 0.2878 L.E./kg under artificial drying at constant air flow rate of 28 $m^3.min^{-1}$ and constant bale size of 10×38×46 cm and under 75 and 65% initial bale moisture contents, respectively.

Conclusion

The present investigation recommended to use artificial drying by the developed dryer under the following conditions:

1. Begin drying with initial bale moisture content of 65%.
2. Use the small bale size of 10×38×46cm.
3. Adjust air flow rate at 28m3min-1.

REFERENCES

Ali, H.M., I.A. Sakr and M.M. Shokry. 1980. Solar dehydration of agricultural products with reference to food nutrients. International symposium on solar energy utilization londen-onatrio, august 10-24. pl-23.

Atia, S.A. 1992. Nutritive value of green forage dried by solar energy master of science in animal production department zagazig university.

A.O.A.C. 1970. Association of official agricultural chemists. Official methods of analysis. 11 ed., Washington, D.C.

El-Sahrigi, A.F., M.F. Hussein, A. Gibril and Y.M. Hassan. 1970. Technological studies on the factors affecting the rate dehydration of onion slices. Ain-Samas U. Fac. of Agric. Cairo Egypt R.Bulletin 691.

House, H.K. and R.P. Stone. 1988. Barn Hay Drying. Fact sheet, ministry of agriculture food and rural affairs.

Paine, F.A. and H.Y. Paine. 1992. A Hand book of food packing. Blackie Academic & Professional, London.

Shoukry, M.M., H.M. Gado, F.I.S. Hilal and A.A. El-Nagar. 1989. *In Situ* and *In Vitro* Evaluation of fodder best and some agriculture. J. Agric. Sci. Mansoura Univ. 1 (4):2724-2729.

Shoukry, M.M., M.A. Tawfek, E.M. Hassono and F.I.S. Hilal. 1990. Forage production and nutritive value of some summer forage hays as influenced by advance in season. J. Agric. Sci. Mansoura Univ. 15 (2) : 1975-1986.

Tchiengue, E. and E. Kaptouom. 1986. Influence of technology factors on the rate of drying vegetables using solar thermal energy. Solar Drying in Africa-

Proceedings of a workshop: 21-24 July – Dakar, Sengal.

Wilkinson, S.M. 1981. Losses in the conservation and utilization of grass and forage. Ann. Appl. Bio. 98: 365 – 375.

UK, Electricity Council, Farm-Electric Centre. 1985. Hay drying. A guide to the practical design of installations. Farm-Electric Handbook series.

دراسة بعض العوامل الحرارية المؤثرة علي انتاج بالات الدريس

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يعتبر دريس البرسيم من أهم الأعلاف للحيوانات خاصة في فصل الصيف حيث يحتوي علي معظم العناصر الغذائية للحيوان وخاصة البروتين لذلك لابد من الحفاظ علي الخواص الكيميائية والفيزيائية للدريس من أجل الحفاظ علي قيمته الغذائية ولهذا تم عمل هذه الدراسة لدراسة بعض العوامل الحرارية المؤثرة علي إنتاج بالات الدريس بهدف الوصول الي أنسب طريقة لتجفيف البرسيم وأفضل نسبة رطوبة للكبس وأفضل أبعاد للبالات وأفضل معدلات تدفق للهواء للحصول علي أفضل قيمة غذائية للدريس باقل طاقة مطلوبة وأقل تكاليف.

وكانت عوامل الدراسة هى:

١- طريقة التجفيف الطبيعي؛ طريقة التجفيف الصناعي (باستخدام المجفف المطور) وتحت طريقة التجفيف الصناعي (المجفف المطور) تمت دراسة العوامل التالية:

أ- نسب رطوبة ابتدائية للبالات ٧٥، ٦٥%.
ب- ثلاثة ابعاد للبالة ١٠×٣٨×٤٦، ٢٠×٣٨×٤٦، ٣٠×٣٨×٤٦سم.
جـ- ثلاثة معدلات تدفق للهواء ٢٨، ٣٦، ٤٤ م^3/دقيقة).

وقد أسفرت نتائج الدراسة عن الحصول علي دريس بأفضل خواص فيزيائية وكيميائية نتيجة إستخدام التجفيف الصناعي (بإستخدام المجفف المطور) تحت الظروف الآتية:

- نسبة رطوبة إبتدائية للبالات حوالى ٦٥%.
- أبعاد للبالة ١٠×٣٨×٤٦ سم.
- معدل تدفق للهواء ٢٨ م^3/دقيقة.