Drying rate of hemp conditioned with a forage conditioner

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2 authors:

Jude Liu
Pennsylvania State University

Ying Chen
University of Manitoba

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J. LIU and Y. CHEN

Department of Biosystems Engineering, University of Manitoba, Winnipeg, MB, Canada, R3T 5V6. *Received 10 January 2000; accepted 21 November 2000.*

Liu, J. and Chen, Y. 2000. **Drying rate of hemp conditioned with a forage conditioner**. Can. Agric. Eng. 42:201-204. Mechanical conditioning experiments of hemp were conducted at two growth stages (fibre stage and seed stage) with a forage mower-conditioner consisting of two intermeshing rubber rolls. Conditioned hemp was placed on a mowed lawn in a yard to be naturally dried. Drying rates of hemp were examined by measuring the moisture losses through a three-day drying period at each stage. Drying curves for the two stages showed similar trends. However, a higher drying rate was observed for the hemp at the fibre stage which was initially wetter (71% versus 59% moisture content on wet basis). Four different roll pressures between 0.3 and 6.6 N/mm were used for conditioning. Conditioning was effective in increasing the drying rate of hemp. A roll pressure of 2.4 N/mm appeared most effective for drying at the fibre stage and 4.5 N/mm at the seed stage. **Keywords**: hemp, conditioning, roll pressure, drying rate.

Le conditionnement mécanique du chanvre a été réalisé pour deux stades de maturité de la plante, celui associé à la maturité des fibres et celui où les graines sont à maturité. Le conditionnement a été effectué avec une faucheuse-conditionneuse comprenant deux rouleaux crénelés en caoutchouc. Le chanvre conditionné a été placé sur une surface engazonnée lors des essais de séchage naturel. Les taux de séchage du chanvre ont été caractérisé par la mesure des pertes en eau durant un cycle de séchage de trois jours pour chacun des stades. Les courbes de séchages montrent des tendances similaires pour les deux stades de maturités du chanvre. Cependant, le taux de séchage du chanvre au stade de maturité idéal pour les fibres a été plus élevé alors que sa teneur en eau initiale était plus élevée (71% contre 59%, sur une base pondérale humide). Quatre niveaux de force entre 0.3 et 6.6 N/mm ont été appliqués sur les rouleaux durant les essais. Le conditionnement augmente le taux de séchage du chanvre ainsi que son coefficient caractéristique. Une force de 2.4 N/mm appliquée sur les rouleaux semble optimale pour hâter le séchage du chanvre au stade de maturité des fibres, alors que les meilleurs résultats de séchage pour le stade des graines sont obtenus avec une force de 4.5 N/mm. **Mots clefs**: chanvre, conditionnement, niveaux de force sur les rouleaux, taux de séchage.

INTRODUCTION

Interest in hemp and its abundant possible uses has increased rapidly in recent years. As a result, the cultivation of hemp in Canada reached 120,000 ha in 1999. Due to four decades of prohibition of hemp farming, research and development of hemp machinery was stopped. Hemp growers are presently using commercial agricultural equipment designed for other crops.

Both seed and fibre can be harvested from a hemp plant. For the largest quantity and the best quality of the fibre, hemp should be harvested at its early growth stage. Harvesting of fibre hemp should begin when one-third of the anthers in the male flowers are open, and be completed before female flowers open (Bócsa and Karus 1997). At its late growth stage, seed is harvested and coarse fibre obtained simultaneously. These two stages are referred as “fibre stage” and “seed stage” in this paper. For either stage, hemp stalks need to be dried in the field before baling and storing. At the fibre stage, the whole plant is swathed and naturally dried in the field while at the seed stage the seed-head is harvested first and only the remaining part of the plant needs to be dried.

Bócsa and Karus (1997) indicated that due to its massive swath, hemp requires longer time to dry naturally than other crops, such as cereals and forage. The moisture content of hemp should be less than 16% (wet basis) when the swath is baled to avoid development of mould inside bales. Bócsa and Karus (1997) also reported that, depending on weather conditions, a minimum of two to three turnings of the swath is required to accelerate the drying process. Mechanical conditioning is expected to be useful to reduce field drying time, especially at the fibre stage when hemp is at a high moisture content. Huisman et al. (1994) reported that the drying rate during the first two weeks of field wilting was initially higher for conditioned hemp as compared to unconditioned.

Mechanical conditioning to accelerate the drying of other crops has been studied. Factors such as roll spacing (Descôteaux and Savoie 1999), roll pressure (Savoie and Beauregard 1989; Chung and Verma 1982),and slippage between crop and conditioning rolls (Klinner and Hale 1984) have been tested. Little research has been done on hemp conditioning. The objectives of this research were: (1) to examine the drying rate of hemp at two growth stages and (2) to study the effects of different conditioner roll pressures on hemp drying.

MATERIALS and METHODS

Hemp was grown south of Winnipeg, Manitoba, Canada. Plant population, height, and dry matter yield were determined by taking six random 1 m^2 samples. The corresponding values were 18.6 plants/m^2, 2.1 m, and 5.8 t DM/ha. The weather data for the periods of drying tests (Table I) were obtained from the Point

Table I. Weather conditions during the conditioning tests for fibre and seed stages of hemp. Data were obtained from the Point Weather Station, University of Manitoba for 1999.

Date	Air temperature (°C)		Mean soil temperature at 25 mm depth (°C)	Precipitation (mm)	Solar radiation (MJ/m^2)
	Minimum	Maximum			
Fibre stage					
August 17	15.4	24.3	19.2	4	8.3
August 18	14.5	25.2	19.4	0	16.2
August 19	12.1	28.5	19.9	0	17.5
August 20	13.7	28.7	20.9	0	13.1
Seed stage					
September 21	8.2	26.0	14.3	0	14.2
September 22	7.3	24.4	14.8	0	6.5
September 23	5.3	19.0	13.9	0	13.5
September 24	4.2	23.7	13.9	0	13.0

Weather Station, University of Manitoba, which is located approximately 10 km from the drying site. The soil temperatures at a depth of 25 mm during the drying tests were included in Table I because hemp was dried naturally on the ground.

Conditioner

A commercially available forage mower-conditioner (referred to as conditioner hereafter) (Model 499, Ford New Holland Inc., New Holland, PA) was used in this study. The conditioner features two intermeshing rubber rolls with a diameter of 264 mm and a length of 2794 mm. The roll pressure can be adjusted from 0.3 to 6.6 N per millimetere of roll length. (Although this parameter is technically a force per unit length and not pressure, the term roll pressure will be used in this paper to be consistent with the manufacturer's literature.)

Since the conditioner was designed to handle a forage crop, it was not used for cutting the hemp so as to avoid the risk of damaging the equipment by the higher cutting strength required to cut hemp. A 6.7-m John Deere 2360 swather which had previously been tested for hemp swathing was used to swath the hemp before conditioning tests.

Experimental design and procedure

Two experimental trials were conducted in 1999 at the fibre stage (August 18-20) and the seed stage (September 22-24). For each trial, a completely randomised experimental design was used with three replications and four treatments: four roll pressures, P1 = 0.3, P2 = 2.3, P3 = 4.5, P4 = 6.6 N/mm, and control (no conditioning). The pressures included both minimum and maximum roll pressures recommended by the conditioner manufacturer and two intermediate roll pressures.

It was observed that there was an extremely uneven hemp plant distribution along the windrow due to the tall plant and high stubble after swathing. This situation was not ideal for uniform drying. Field conditions would also cause difficulties in monitoring the hemp moisture loss. To have a better controlled drying environment, swathed hemp was taken to a yard at the Glenlea Research Station, University of Manitoba. Hemp was manually placed in windrows in the yard. The rolareel header of the conditioner used its converging reels to sweep the windrow directly into the conditioning rolls. The rotation speed of the conditioner rolls was maintained at 665 rpm for all trials. The conditioned hemp was placed on a mowed lawn in the yard. For each stage, hemp conditioning was completed by 14:00 hour.

Measurements

Before conditioning, three random samples were hand collected in each trial for determination of the initial moisture content. Samples were oven-dried at 60ºC for 72 h. After conditioning, approximately 10 kg of hemp was collected from each treatment and placed on a meshed tray (1.5×1.2 m) to naturally dry. To monitor the water losses, trays were weighed immediately after conditioning and every 2-4 hours thereafter during daylight from 8:00 hour to 20:00 hour in the yard drying trials. Due to bad weather, drying rate measurements in the yard trials were terminated after approximately 50 hours, which was before the hemp reached a safe moisture content for balling. However, the drying period covered the most critical stage of drying as the effect of conditioning in drying rate diminishes with time (Savoie et al. 1997).

Data analysis

Analysis of variance (ANOVA) (Steel and Torrie 1980) was performed on moisture contents of hemp at different drying times and drying coefficients for different treatments with Statistical Analysis Software V6.12 (SAS/STAT 1990). The multiple comparison method with the Duncan's multiple-range test was used to detect the differences among treatment means at a significance level of 0.05. Significant differences were not detected between replications and means were pooled for each treatment across the replications of each trial. Regression analysis relating drying time to moisture content was also performed to find the drying coefficients of different treatments at different time intervals.

RESULTS and DISCUSSION

Effects of growth stages on drying rate

The initial moisture content of hemp was 70.7% (wet basis) at the fibre stage and 58.8% (wet basis) at the seed stage. The trends of the drying curves were similar for both growth stages although the initial moisture contents and weather conditions were different (Fig. 1). The drying rate at the fibre stage was higher than at the seed stage, for all roll pressures, especially at the beginning of the drying process. This was due to the higher initial moisture content at the fibre stage. The moisture content averaged over four treatments at the fibre stage after 50 h decreased 22 percentage points, while that at the seed stage decreased 13 points. The difference in moisture content between the fibre stage and seed stage decreased with the increasing of drying hours. After 50 h of drying, the difference was reduced from the initial value of 12% to 8%.

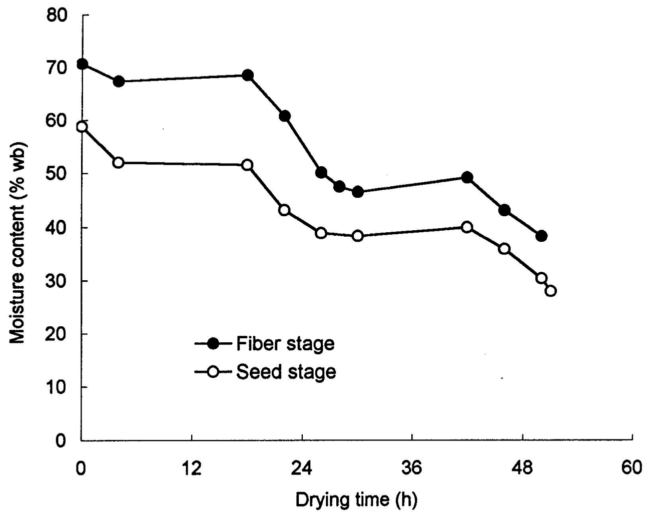

Fig. 1. Drying curves of conditioned hemp at the fibre and seed stages. Measurement of moisture content started at 14:00 h for both stages.

Table II. Moisture contents (wet basis) averaged over three replications at different drying times at the fibre stage.

Time	P 1	P 2	P 3	P 4	C*
14:00	70.7*a***	70.7*a*	70.7*a*	70.7*a*	70.7*a*
18:00	66.4*a*	67.0*a*	68.3*a*	67.8*a*	67.8*a*
08:00	68.2*a*	68.1*a*	68.7*a*	69.0*a*	69.2*a*
12:00	61.2*a*	60.2*a*	59.5*a*	62.0*a*	63.0*a*
16:00	50.3*b*	48.5*b*	49.8*b*	51.7*ab*	55.1*a*
18:00	47.7*ab*	45.6*b*	47.5*b*	49.0*ab*	52.7*a*
20:00	44.5*b*	45.3*b*	47.5*ab*	48.7*ab*	52.2*a*
08:00	48.5*ab*	48.0*b*	49.3*ab*	50.6*ab*	52.9*a*
12:00	42.3*b*	41.1*b*	44.0*ab*	44.8*ab*	48.3*a*
16:00	38.2*b*	35.4*b*	38.8*ab*	40.7*ab*	44.6*a*

* C = Control.
**Values with same letter in the same row are not significantly different (P=0.05) based on Duncan's multiple range test.

Effects of roll pressure on drying rate

At the fibre stage, there were no significant differences in moisture content among the conditioning treatments and the control before 12:00 hour on the next drying day (Table II). After 26 h of drying, the moisture contents for the conditioned material at P1 (0.3 N/mm) were significantly lower compared to those for the unconditioned hemp. The treatment P2 (2.4 N/mm) seemed most effective for drying, followed by the treatment P1. The hemp plant, especially the seed-head part, was compressed together when the roll pressure was P4 (6.6 N/mm) and the material density became higher. This might explain the slower drying rate showed at this roll pressure.

Table III. Moisture contents (wet basis) averaged over three replications at different drying times at the seed stage.

Time	P 1	P 2	P 3	P 4	C*
14:00	58.8*a***	58.8*a*	58.8*a*	58.8*a*	58.8*a*
18:00	52.4*a*	52.6*a*	51.1*b*	52.2*ab*	53.4*a*
08:00	51.4*bc*	52.1*abc*	50.3*c*	52.4*ab*	53.5*a*
12:00	42.3*b*	43.4*b*	42.1*b*	44.7*ab*	47.0*a*
16:00	38.8*b*	39.1*b*	37.7*b*	39.7*ab*	43.0*a*
20:00	38.0*b*	39.2*b*	37.7*b*	38.3*b*	42.3*a*
08:00	39.4*b*	40.9*ab*	39.2*b*	40.3*ab*	42.8*a*
12:00	36.0*b*	36.5*b*	34.6*b*	36.4*b*	40.2*a*
16:00	30.4*a*	31.0*a*	29.7*a*	30.3*a*	32.8*a*
17:00	28.0*a*	27.8*a*	27.0*a*	29.1*a*	30.6*a*

* C = Control.
**Values with same letter in the same row are not significantly different (P=0.05) based on Duncan's multiple range test.

At the seed stage (Table III), the effects of conditioning on drying rate appeared earlier compared to the fibre stage. After 4 h of drying, the treatment P3 (4.5 N/mm) yielded the higher drying rate, followed by the treatments P2 and P1, as compared to the control. There were no significant differences in moisture content among the treatments after 42 h of drying, when hemp was dried down to the moisture content of approximate 30%. The treatment P3 appeared the most effective during the drying period of 4-42 h. At the seed stage the characteristic of hemp drying rate influenced by roll pressure was similar to that of macerated alfalfa which was obtained by Savoie and Beauregard (1989).

Effects of conditioning on drying coefficient

The typical field drying equation for alfalfa as suggested by Rotz and Chen (1985) is:

$$\frac{M}{M_0} = \exp(-kt) \tag{1}$$

where:

- M = moisture content (dry basis) at end of time interval,
- M_0 = moisture content (dry basis) at beginning of time interval,
- k = drying coefficient (h^{-1}), and
- t = time interval (h).

The regression analysis showed that Eq. 1 can be used to describe the drying process of hemp in the range of 70 to 30% moisture content with coefficient of determination (R^2) of over 0.93. Since the rate of moisture content decrease became smaller with time (Fig. 1), different drying coefficients for different time intervals will better describe the drying process. Drying coefficients were calculated with Eq. 1 for two time intervals, 0-26 h and 0-50 h, and their differences among the treatments were statistically analysed for each stage (Table IV).

Table IV. Drying coefficients for hemp for different treatments for two drying time intervals at two growth stages.

Treatment	Drying coefficient, k (h^{-1})			
	Fibre stage		Seed stage	
	Time interval 1*	Time interval 2	Time interval 1	Time interval 2
Control plot	0.0260*b***	0.0220*b*	0.0245*b*	0.0215*a*
P1	0.0334*a*	0.0272*a*	0.0313*a*	0.0238*a*
P2	0.0361*a*	0.0296*a*	0.0308*a*	0.0232*a*
P3	0.0341*a*	0.0267*ab*	0.0330*a*	0.0244*a*
P4	0.0313*ab*	0.0252*ab*	0.0297*ab*	0.0238*a*

* Time interval 1 = 26 h from initial drying to 16:00 h of next drying day.
Time interval 2 = 50 h from initial drying to 16:00 of the third drying day.

** Values with same letter in the same column are not significantly different (P=0.05) based on Duncan's multiple range test.

At the fibre stage, the drying coefficient was 35% higher during the time interval 1 and 25% higher during the time interval 2, when the roll pressure was P1 or P2 compared to the control. At the seed stage, significant differences in the drying coefficient between treatment and control were observed only for the time interval 1 at the P1, P2, and P3 roll pressures, possibly due to the low initial moisture content of the hemp.

CONCLUSIONS

1. In most cases conditioned hemp had a significant higher drying rate than unconditioned hemp over a drying period of 50 hours, at both the fibre and seed stages. Drying rate was higher at the fibre stage than the seed stage during the period studied.
2. Roll pressure influenced the drying rate of hemp. The most effective roll pressure was 2.4 N/mm for conditioning hemp at the fibre stage and 4.5 N/mm at the seed stage which had a lower initial moisture content. The drying coefficients indicated that the maximum pressure, 6.6 N/mm, was not effective for hemp conditioning at the either growth stage.

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