Developing of a Prototype for Fiber Sorghum Harvesting

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ABSTRACT

Among the energy crops Fiber Sorghum is becoming an interesting one, due to its annual cycle and its high drought adaptability. Moisture content is around 75 - 80% at the harvest time and, in order to preserve the product for the whole year, it must be decreased under the 30%. An intensive conditioning is an important aspect in order to reach a humidity content such that to enable harvesting and storability in acceptable times. Within the Bio-energy project, CRA-ING, developed a prototype able to highly conditioning fiber sorghum and in collaboration with S.F.I.R and Co.Pro.B. Italia Zuccheri, conducted different experimental tests on Fiber Sorghum crops with different degree of growth, different moisture content and different harvesting times. During the 2007 and 2008 years, CRA-ING worked on the modification of the conditioning bars thickness of the prototype in order to obtain a good conditioning degree, avoiding the risk of product cutting off. The second year tests (summer 2008), in fact, showed the good performances of the prototype modifications. The results of the experimental tests on the fiber sorghum dehydration showed the possibility to reach the 25% of humidity in 5 days without windrow turning and 4 days turning the windrow the 3° day, in good climatic conditions.

Keywords: Fiber sorghum, harvesting, energy crops, haymaking, mower conditioner, Italy.

1. INTRODUCTION

Among the alternative biomass crops, Fibre Sorghum is gaining a lot of interest due to its annual cycle and its high drought adaptability. One of the problems related to energy crops like this, is the importance of decreasing production costs and harvest times.
In addition, the need to reduce the biomass moisture content in order to decrease the transport costs and allow for storage without fermentative phenomena occurring is a main challenge for the agro-energy chain.
The harvesting experiments of the previous years conducted by the means of mower-conditioner, side-delivery rake and packers, represent the first step for the development of a prototype that solves the difficulties previously encountered.
In 2007, CRA-ING conceived and developed a mowing machine that permits the cutting and conditioning of the whole plant by deep cracking of the stems. The results of previous experimental tests conducted with the CRA-ING prototype have provided interesting results by

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reducing sun exposure times enough to obtain the right moisture content for the baling, handling and preservation of the product.
Within the Bio-energy project, CRA-ING developed a prototype that is able to highly condition Fibre Sorghum and, in collaboration with S.F.I.R. – Società Industriale Romagnola S.P.A. and Co.Pro.B. Italia Zuccheri – have conducted different experimental tests on Fibre Sorghum with different degrees of growth, moisture contents and harvesting times.

2. MATERIALS AND METHODS

The first year's testing results showed a good machine performance (Supplemento Informatore Agrario 05/2009), but some limits due to the aggressive action of the conditioner rollers, causing (at times) the cutting and softening (exhausting) of the culms and the frequent excision of stems and the inevitable machine flooding.

During winter, the conditioner rollers were modified in order to reduce the aggressive action of the conditioning bars and blades, making adjustable the power take-off and conditioning according to the characteristics of Fibre Sorghum growth. Thus, the conditioning bars (Fig. 1) were replaced by bars with a different thickness and profile.

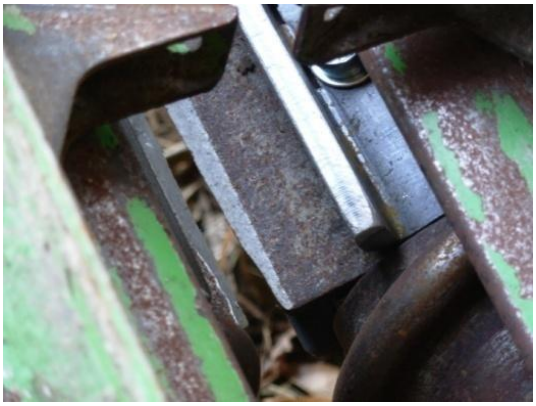
Figure 1. New conditioning

In addition, the positioning of the blades was modified in order to reduce the aggressiveness of the conditioning to a minimum level in the front and higher level in the rear (Fig. 2).

Figure 2. Specification of the new conditioning bars

The first tests with the modified prototype were conducted in July 2008. An experimental field with a total area of 1.7 ha was prepared by Co.Pro.B in Massa Finalese (in the province of Modena).
The drying times of the plants were surveyed until their minimum values were low enough to preserve them in bales (Chiumenti, 1979). Five areas were selected for the daily sampling of whole plants (including stems, leaves and ears) from the mowing day, on which, according to the CEN/TS 15414-1:2006 (CEN/TS, 2006), the degree of moisture was calculated. Surveys went on until the minimum values were low enough to preserve plants in bales. Following a careful study of the ways that plants are discharged by the machine, it was chosen to sample whole plants. The cracked plants, in fact, did not appear uniformly distributed, instead falling one upon another because of the advancing speed and conditioning system of the longitudinal rollers. So, without further intermediate pre-harvesting working, the biomass harvested will require different lengths of time to dry depending on the quantity of the aboveground biomass. Each plant that was cut and longitudinally cracked was covered by about 50% by other plants. Whole plants were sampled with the aim of obtaining an average moisture value between that of the biomass directly exposed to radiation (apical part) and that of the biomass not so directly exposed (basal part).

3. RESULTS

3.1 Working Capacity

The machine was formed by combining a CRA-ING prototype with a New Holland G240 tractor equipped with a reversible drive whose main technical features are reported in the following table (Table 1).

Table 1. The main features of the machines used in the proof

Typology	Manufacturer	Model	Dimensional aspects	Parameter
Tractor	New Holland	G240	Type	DT-reversible guide
			Power (kW)	178,96
Mower-conditioner machine	CRA-ING	Prototype	Working width (m)	2,7

The regular shaped field in Massa Finalese was characterized by the homogeneous growth of Fiber Sorghum (Table 2).

Table 2. Main characteristic of the proof plot and the crop during surveys

Parameter	Unit of measurement	Value
Site	Coordinates GPS	44°52’30”N - 11°13’23”E
Lenght	m	330
Width	m	23
Area	ha	0,759
Height	m	330-340
Sowing inter-row	m	0,45
Density at harvesting	plants/m^2	15

The soil preparation, crop sowing and crop treatment were completely prepared by Co.Pro.B (Table 3). According to the data provided by them, the proof plot was not irrigated or fertilized.

Table 3. Technical and agronomic aspects related to the proof field of Massa Finalese provided by Co.Pro.B.

Operation	Typology	Period of time
Soil preparation: primary processing	Ploughing	07/2007
Soil preparation: secondary processing	Weeding	09/2007
Soil preparation: secondary processing	Harrowing	11/2007
Sowing	Precision	14/04/2008
Sowing density	Plants/m^2	18,5

The crop mowing/conditioning was conducted in the date of 23/07/08 and 28/07/09 (Fig. 3 and 4).

Figure 3. Particular of degree of crop growth

Figure 4. The machine operating data for 23/07/08

The machine operating values recorded during the mowing are listed in the following table (Table 4).

Table 4. Working parameters recorded and calculated during mowing-conditioning

Parameter	Unit of measurement	Value
Rotation motor capacity	Rpm	1400
Rotation pdp capacity	Rpm	690
Working speed	m/s-km/h	1,6-6,0
Operative working capacity	ha/h	1,62
Effective working capacity	ha/h	1,42
Cut height	m	0,2

In spite of the contained working width of the prototype (2.7 m), the machine showed a successful result (over 1.4 ha/h), mainly due to the plot dimensions (length of more than 14 times the width).
In addition, the modification of the conditioning system improved the working capacity of the machine, considerably reducing the occurrence rate of the excision of the more turgid stems.

3.2 Conditioning Efficiency

The decrease in the aggressive action on plants obtained with the developed modifications to the machine could result in prolonging the time of drying.
The difference in the moisture content of the crop during the day seems to have an impact on the group conditioning efficiency. Especially with respect to mowing, an increased tendency for the excision of the stems was noticed in the morning compared to when the machine was operated in the afternoon. Resting time to remove stems piled up in the rear part of the prototype was not required.
After operation, plants are packed with deep crushing of their stems, as well as with small cuts that allow matter to get out every 3.5 cm (Fig. 5).

Figure 5. The effect of conditioning on the plant

3.3 Drying Curve

In July 2008, in the proof area, the climate trends was characterized by an average temperature of 26 °C and an average humidity of 55% (with two rainy days and a storm (43 mm rain) the 27th of July preceeding the mower conditioning and the product dehydration in field). In Table 5, the main values of temperature and moisture recorded in the work area are provided.

Table 5. Weather condition surveyed in the working area

Date	Average T° (°C)	T°min (°C)	T°max (°C)	U (%)	Rains (mm)
27 July 2008	27	20	33	64	43
28 July 2008	28	22	34	61	-
29 July 2008	28	21	35	55	-
30 July 2008	28	21	35	55	-

The surveys regarding the speed of drying for the biomass were carried out in the mowed area on

the second day of the trial (28/07/08), whereas on the first day (23/07/08) the mowing machine was assembled.
In Fig. 6, the moisture values recorded in the five areas sampled are reported. The values mainly seem to differ in regards to the position of the plant after the passage of the mower machine, particularly with regard to the degree of exposure to solar radiation. There are also samples with similar values, due to the similarity in the size of the plant as well as the position of the plant in the layer that modifies the degree of exposure to solar radiation.

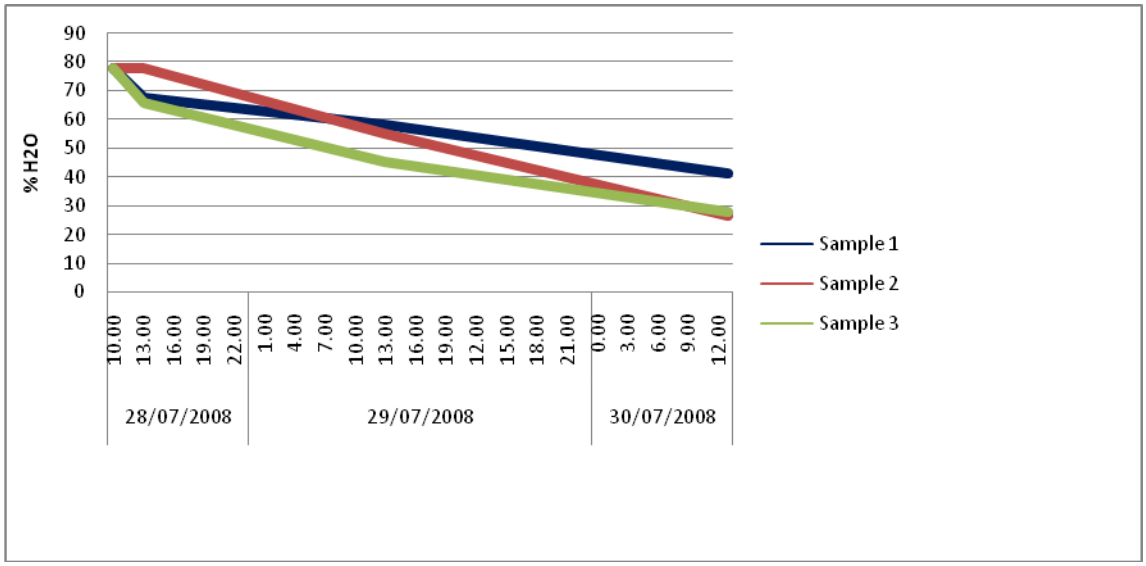

Figure 6. Moisture values of the samples taken

The analysis conducted shows how the water content of the plant tissue was considerably reduced in two days due to the deep cracking that allows for the immediate leakage of liquids that dry out just as they are exposed to the sun. The impact of this process decreases as the difference between the moisture of the air and plant tissues decreases.
In Fig. 7, the average values of five samples taken immediately after the machine passed by (10:00) are reported, (at 13:00 of 23/07/08 and at 13:00 of the 29/07/08). In the hours after the mower machine had passed, a greater reduction in the moisture content was observed (12.69%) than on the day after the machine had passed (11.92%).

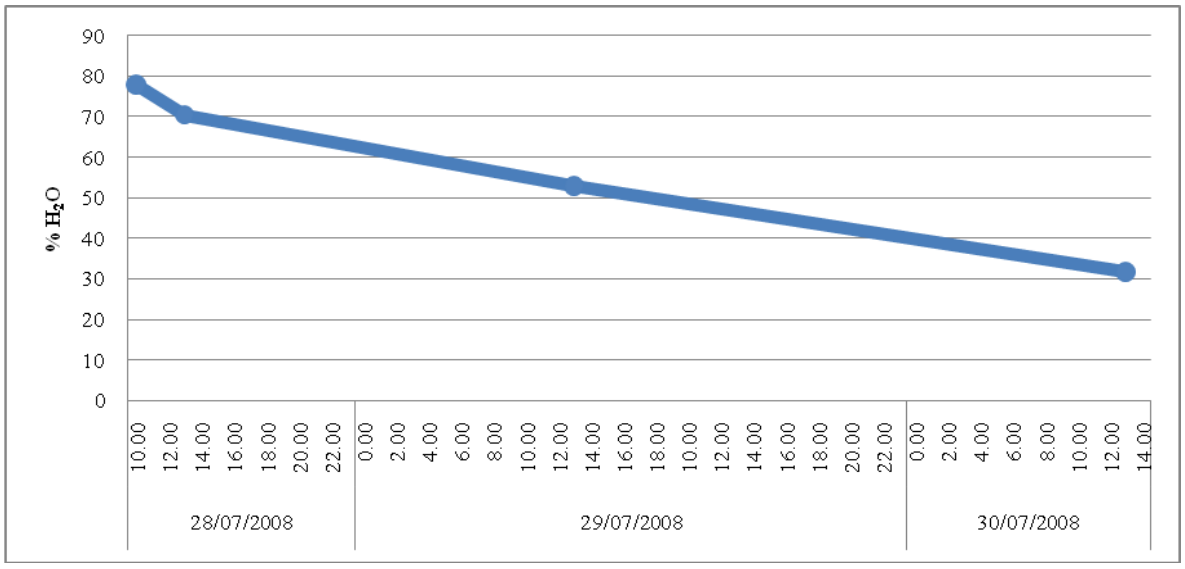

Figure 7. Natural drying in the field: average curve

The fact that the turnings were not carried out caused a progressive slowdown of dehydration in the deepest layers, whereas, on the surface, the minimum moisture necessary for preservation was plentifully reached.
A suitable moisture for preservation (<30%) after harvesting (Fig. 8) was obtained in four days. Based upon previous experiments (August 2007), a middle tedding executed at the end of the 2nd day or at the morning of the 3rd day could reduce the time between the mowing/conditioning and the final harvesting by a day, allowing windrowing and baling in the late afternoon of the next day.


Figure 8. Particulars of the conditioned plant

The overall productivity of the crop was 7.76 t/ha, a good result if we consider the advance harvesting date and profit when growing for 30 days less.

4. CONCLUSIONS

The results of the experimental tests of September 2007 on the dehydration of Fibre Sorghum

show the possibility for reaching a moisture of 25% within 5 days without windrow turning and 4 days when turning the windrow on the 3rd day, in good climatic conditions.
The prototype modified for the experimental tests conducted in Massa Finalese in July 2008 allowed for the attainment of a product ready to bale (with no need for other processing) in the same time as the tests from the previous year, and without any turning.
The reduction of the aggressive conditioning system of the prototype did not affect its effectiveness and allowed for a remarkable reduction in the necessary rest time that was due to the machine flooding, with an increase in the working capacity (>1.4 ha/h).
It is important to highlight that the harvest time of the experimental proof described above corresponds to the period of maximum solar radiation, and at the same time, the crop was characterized by a lower degree of growth with respect to the traditional techniques of Fiber Sorghum production and harvesting.
The prototype developed by CRA-ING allowed for a reduction of over 50% of the stay times of the biomass in the field in respect to other haymaking systems (Barbucci et al, 1992).

5. REFERENCES

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