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ORIGINAL ARTICLE

Cost effective drying for high quality tender wheatgrass powder

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Abstract

Tender wheatgrass is 8 to 10 days plant grown from bold wheat seeds. It has maximum health benefits like an advance therapy for cancer as well as thalasemia disease. However its benefits are limited to those individuals who grow it daily and consume in fresh form or by juicing it immediately after cutting of the tender wheatgrass. In order to ease the adaptability of tender wheatgrass, the wheatgrass was grown in multi shelves rack, which has an advantage in terms of multifold utility of space available and efficient use of water. Out of different drying methods used to dry tender wheatgrass having initial moisture content of 5.02 kg per kg dry matter, forced air solar drying was found to be acceptable on the basis of lower drying temperature (42-43°C) and less drying time of 270 min, with desirable quality as lower final moisture content (0.05 kg per kg of dry matter), higher chlorophyll content (0.134 g per 100 g dry matter) and considerable retention of ash, fat and protein contents when drying was accomplished by spreading wheatgrass at 0.25 to 0.30 kg/m^2 density and using air flow at rate of about 0.17 m/s in drying chamber. The forced air shade drying of wheatgrass could be completed in 720 min keeping air velocity and spreading density of wheatgrass similar as in prior case, ensuring chlorophyll content of 0.135 g per 100 g dry matter and other contents with comparable limits in the dried matter. Grinding operation for preparation of wheatgrass powder could be carried out well under the refrigerated condition. Wheatgrass drying carried out by different methods could be predicted with help of Page equation with considerably high coefficient of determination i.e., more than 0.94.

Key word: Wheatgrass, powder, drying, therapy, chlorophyll

Introduction

Tender wheatgrass is 8 to 10 days plant grown from bold wheat (*Triticum aestivum*) seeds (Murphy and Sean, 2002; Kulkarni et al., 2006). Tender Wheatgrass, hereinafter, termed as Wheatgrass, is renowned for its therapeutic value since ancient times. The tender wheatgrass contains vitamins, minerals, enzymes, chlorophyll and 17 amino acids. Apart from the above mentioned nutrients, tender wheatgrass also contains agropyrene, apigenin, and abundant antibiotic, anti oxidant and anti-inflammatory properties (Anonymous, 2008).

Nutritional value of 25 g of fresh wheatgrass juice is approximately equivalent to 1000 g of fresh vegetables (Melina et al., 2003). Wheatgrass can be used either in fresh form (Murphy and Sean, 2002) (juice, cut grass, etc.) and dried form (Murphy and Sean, 2002;

Anonymous, 2007) (powder, tablets or capsules, etc.). Growing wheatgrass for daily availability to consume in fresh form is difficult and tedious task, thus most of the people do not opt to use the wheatgrass. Therefore, in order to ease its adaption, the enmass growing and drying can be opted to make available the wheatgrass to the common people.

Wheatgrass must be dried at lower possible temperature, so as to prevent loss of the sensitive elements (Anonymous, 2009a). For this purpose, spray dried (Murphy and Sean, 2002) and freeze dried (Murphy and Sean, 2002; Sagliano and Sagliano, 1998) powder from wheatgrass juice is the most competent option, but it is a costly affair. The attempts made to commercially preserve wheatgrass through vacuum drying processes indicated that the elevated temperatures to which the product was exposed during this processing resulted into the product that was inconsistent in composition, had a poor flavor and was diminished in nutrient assay, particularly showing a marked decrease in levels of viable enzymes (Sagliano and Sagliano, 1998). Therefore, the drying processes like sun drying, shade drying, solar drying with natural air draft, forced air solar drying, forced air shade drying were undertaken to select the appropriate and cost effective drying process for drying of tender wheatgrass. In view of the aforesaid discussion, the present investigation was undertaken with the specific objectives to study various drying methods for drying of tender wheatgrass and to evaluate quality characteristics of wheatgrass powder to select appropriate drying method for tender wheatgrass.

Materials and Methods

Growing and cutting of tender wheatgrass: Growing of tender wheatgrass (Sagliano and Sagliano, 1998) included soaking the wheat seed in water for overnight and germinating them for next 12 hours, by keeping it in aerated pot or by tying in muslin cloth and spreading them over the soil or in the trays with soil and kept on shelves of multi-tier rack, by avoiding overlapping of the seeds. After that, the soil was lightly sprinkled to cover the seeds. The growing area or the racks may be covered with 50% green shade net so as to provide natural air flow and avoid direct sunlight. Regular watering was done as and when required during the growing period. The rack could have four to six shelves, each having growing floor area of 80 cm x 120 cm and placed one above other with vertical spacing of 25 to 30 cm between two successive shelves. The growing of wheatgrass in multitier rack can obtain 4 to 6 fold more wheatgrass than that in field. The wheatgrass of 8 to 10 days (Murphy and Sean, 2002), was cut manually by seizer and collected for its drying. It yielded about 1.43 g fresh wheatgrass from 1 g wheat seeds used for the purpose (Burbade, 2009).

Drying of tender wheatgrass: The prime requisition for drying of tender wheatgrass is a lower possible drying temperature (Anonymous, 2009d), minimum possible drying time and using feasible means of drying. The drying temperature at higher level like in sun drying (Anonymous, 2009b) affects content of dried material like chlorophyll, minerals, vitamins, amino acids, and many biochemical contents (Anonymous, 2009a). In order to determine the cost effective way of drying for obtaining highest possible quality dried wheatgrass powder, the present investigation was undertaken to study drying of tender wheatgrass using different drying methods like forced air solar drying, solar drying with natural draft, forced air shade drying, shade drying and sun drying. The sample of fresh cut wheatgrass were obtained as discussed above and spread in perforated trays with density of 0.25 to 0.30 kg/m^2 equivalent to thickness of 3 to 5 mm of fresh wheatgrass so as to enable uniform drying. The observations on moisture content, temperature, relative humidity were noted at regular interval during drying.

Forced air solar drying: A laboratory model of forced air dryer was prepared with solar collector cum drying chamber (Sharma *et al*., 1994), as shown in Fig. 1. In this method, the solar collector was made of wooden box with its top inclined at 45° with horizontal and covered with 800 gauge poly sheet. The holes of 15 mm diameter were provided on the sidewalls and front wall of box as inlet for the fresh air and outlet for the moist air was provided by means of chimney (75 mm diameter) installed at rear and upper end of the dryer. The perforated trays were placed one over other inside the drying chamber in such way that the solar insolation received by lower trays would minimally be affected by placement of upper tray. The drying material spread in the perforated trays was subjected to drying forces as solar insolation received through poly sheet and forced air induced by means of the artificial air draft using blower operated with electrical motor (220 V) that was installed at the outlet of the chimney. The velocity of the drying air could be varied by means of butterfly valve provided at the base of chimney. The electrical motor operated blower as in Fig. 1 (a), could be replaced by blower operated using motor powered with solar energy (Sarkar and Saleh, 2002; Itodo *et al.*, 2004) as shown in Fig. 1(b).

Solar drying with natural draft: A laboratory model of forced air dryer as shown in Fig. 1 (a) was used as Solar dryer with natural draft (Singh *et al*., 2005; Sharma *et al.*, 1994) by switching off the blower system, leaving other arrangements unchanged.

Forced air shade drying: A laboratory model of Forced air solar dryer as shown in Fig. 1 (a) was used as Forced air shade dryer by shifting all the set up under the shade, leaving other arrangements unchanged.

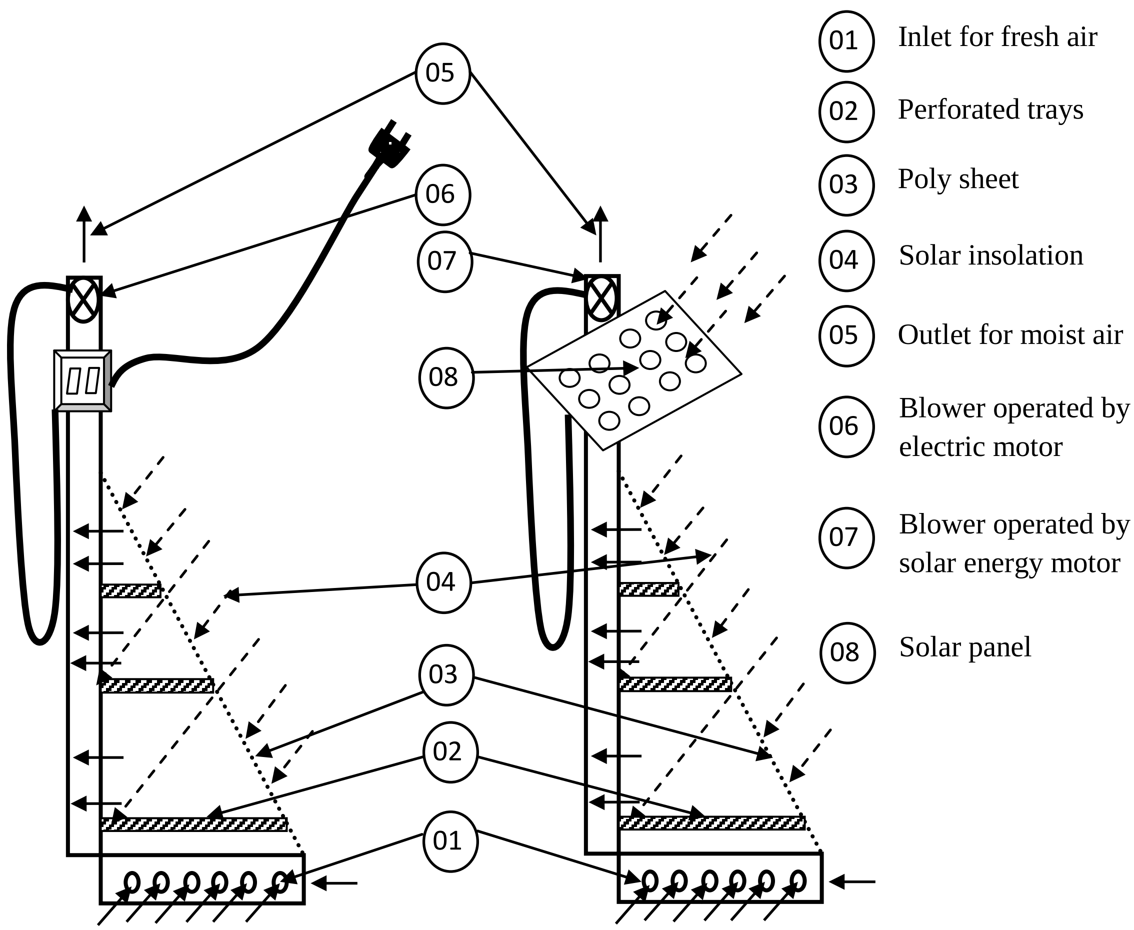

Fig 1: Forced air solar dryer with blower operated using (a) electrical motor and (b) solar energy operated motor

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Shade drying: The shade drying (Ramalakshami *et al.*, 2002) was conducted by spreading the drying material in perforated trays/ net under shade i.e., by avoiding direct exposure to solar radiation.

Sun drying: The drying material was spread in perforated trays/ net exposing it to direct sunlight in open ground throughout the day according to standard drying time from 0900 hrs to 1500 hrs (Mangaraj *et al.*, 2001).

Grinding of tender wheatgrass: Each sample was ground in the grinder kept in refrigerator. The grinder was operated for 10-15 s and rested for next 10-15 min to lower down the temperature inside the grinder. The procedure was repeated for 10 to 12 times till the fine powder was obtained. The ground tender wheatgrass powder was sieved through 106 μ to obtain fine powder. Each sample was analyzed for final moisture content, fat, protein, ash, carbohydrate+ fibre and chlorophyll content. The cold blown air grinding od dried wheatgrass has been reported by Anonymous (2009b).

Mathematical Modeling of Drying Behavior: The empirical equation, $\ln(MR) = \exp^{(-kt^n)}$, proposed by Page (1949) was tried to fit to the experimental data of drying material dried using different drying methods.

Proximate analysis of dried wheatgrass: The Moisture content of samples was determined using hot air oven and following the method suggested by Nilamani (1979). The chlorophyll content was estimated as per Thimmaiah, 2006. The protein and ash content were determined as per AOAC, 1984. The fat content was determined following Ranganna, 1986. The carbohydrates were calculated by difference.

Results and Discussion

Effect of drying methods on quality of dried wheatgrass

Forced air solar drying: The forced air solar dryer developed was tested for effect of velocity of drying air on variation in temperature inside the dryer, at no load condition. From Table 1, it could be observed that with natural air draft, the average temperature inside cabinet of solar dryer rises upto 52 °C as compared to outside temperature of 44 °C while the average temperature inside the cabinet could be reduced upto 42 °C by means of forced air circulated inside the cabinet of solar dryer at velocity of 0.17 m/s.

From Table 2, it could be seen that the sample of fresh tender wheatgrass with average initial moisture content of 5.02 kg per kg dry matter, could be dried using forced air solar dryer up to moisture content of 0.05 kg per kg dry matter in about 270 min. The Equilibrium moisture content (EMC) of the dried samples was observed to be 0.0281 kg per kg of dry matter at average drying temperature of 43.6 °C and average relative humidity of 38.5 %. If the velocity of forced air were increased further using higher capacity blower, still further reduction in drying temperature could be ensured along with reduced drying time. The system can also be operated with blower using motor powered by solar energy as shown in Fig. 1 (b). The automatic control of air velocity and temperature inside the cabinet of solar dryer can be better ensured by solar energy operated blower, as the increased solar insolation would increase air velocity and reduce temperature inside the cabinet of solar dryer and vice versa.

Solar drying with natural draft: Inside solar dryer with natural draft, the average temperature of drying was found to be 50.9°C. The product with average initial moisture content of 5.02 kg per kg dry matter could be dried up to EMC of 0.063 kg per kg of dry matter in about 480 min. The requisite moisture content of 0.05 kg per kg dry matter could not be achieved as EMC was higher than the required moisture content.

Forced air shade drying: Inside forced air solar dryer, the average temperature of drying was found to be 33.6 °C. The product with average initial moisture content of 5.02 kg per kg of dry matter could be dried using forced air shade dryer in about 720 min up to moisture content of 0.05 kg per kg of dry matter and EMC of 0.0394 kg per kg dry matter could be achieved in 750 min of drying time.

Table 1: The air velocity and temperature in forced air solar dryer

Sr. No	Angular opening of butterfly valve	Air velocity in chimney (m/s)	Air velocity in cabinet (m/s)	Outside temp. (°C)	Average temp. in cabinet (°C)
1	With natural draft	-	-	44	52.0
2	Closed	3.5-3.6	0.08	44	43.5
3	30°	3.9-4.1	0.09	44	43.0
4	60°	6.6-6.9	0.15	45	43.5
5	90° (Opened)	7.4-7.8	0.17	44	42.0

Table 2: Drying time, drying temperature, drying rate and EMC for drying of wheatgrass using different drying methods

Drying method	Forced air solar drying	Solar drying with natural draft	Forced air shade drying	Sun drying	Shade Drying
	(1)	(2)	(3)	(4)	(5)
Average Drying temp, °C	43.6	50.9	33.6	42.8	32.9
Average drying rate, kg/kg dry matter per min	0.0344	0.0164	0.0113	0.0370	0.00510
Drying time required to reach moisture content of 0.05 kg per kg dry matter, min	270	480	720	220	1110
Average RH, %	38.5	29	24.5	24	28
EMC, kg per kg dry matter	0.0281	0.0639	0.0394	0.0436	0.0765

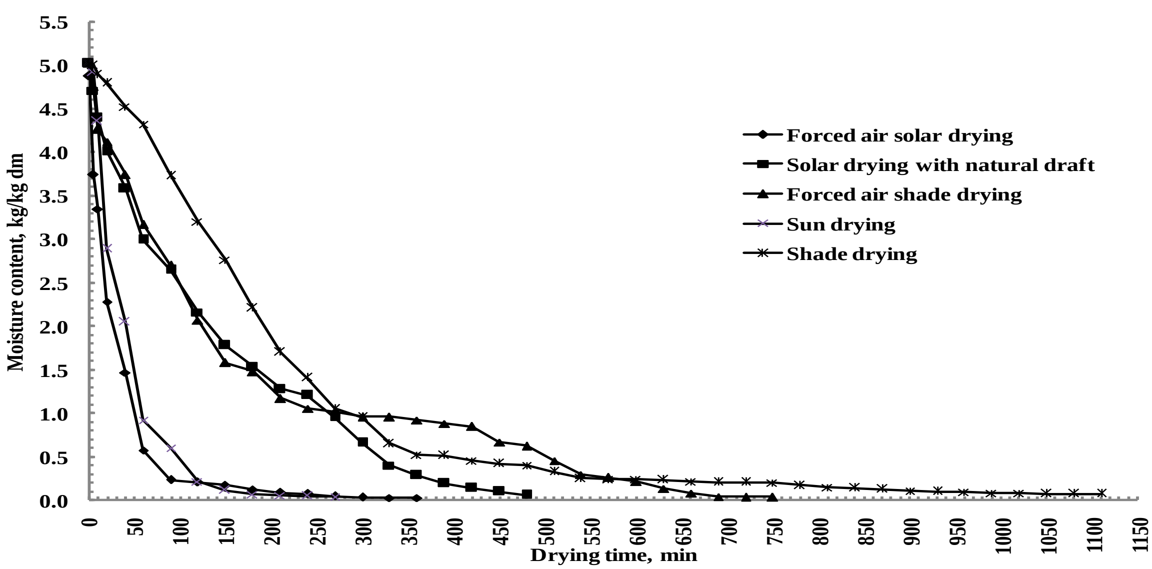

Fig 2: Relation between moisture content (kg/kg dry matter (dm)) and drying time (min)

Sun drying: In this method the average temperature throughout the day time was recorded to be 42.8°C. The product with average initial moisture content of 5.02 kg per kg dry matter could be dried under sun in about 220 min up to moisture content of 0.05 kg per kg dry matter and EMC of 0.0436 kg per kg dry matter could be achieved in 270 min of drying time.

Shade drying: During this drying the average temperature was found to be 32.9°C.The product with average initial moisture content of 5.02 kg per kg dry matter could be dried under shade in about 1110 min up to equilibrium moisture content of 0.0765 kg per kg dry matter, which was above the required moisture content of 0.05 kg per kg dry matter.

Drying characteristics curve: From Fig 2, it could be seen that the trend of moisture removal changed from faster to slower after reaching moisture content of about 0.80 to 1.20 kg per kg dry matter. Table 2 shows that the average drying time required was minimum in case of sun drying (220 min), followed by forced air solar drying (270 min), solar drying with natural draft (480 min), forced air shade drying (700 min) and shade drying (1110 min) to dry the product from its initial moisture content of 5.02 kg per kg dry matter upto final requisite moisture content of 0.05 kg per kg dry matter. The reduced drying time in case of sun drying may be accredited to higher drying temperature (average of 42.8°C) and more exposure to open air. Despite of higher temperature and increased air velocity, the forced air solar drying took more time for drying of sample than that for sun drying, may be due to higher RH (38.5 %). Though the temperature (50.9 °C) was higher and RH (29.0 %) was lower in solar dryer with natural draft than that in forced air solar dryer, the comparative drying time in later case was reduced to half, mainly because of increased air velocity. Due to decreased drying temperature in forced air shade drying, the drying time was 2.5 times more than that in case of forced air solar drying. The low drying temperature and low air flow in case of shade drying, led to prolonged drying (1110 min) of wheatgrass. However, on the basis of requirement of lower drying temperature, and minimum drying time required, the drying methods like forced air solar drying and forced air shade drying could be preferred. The higher drying air velocities could have been resulted into reduced drying time with better result if such provision would have been there in the present drying systems. Chakraverty (2000) has reported that the drying air velocities ranged between 0.1 and 0.68 m/s do not affect the drying rates of wheat grain significantly in thin layer drying. However, the drying air velocities of 1.67 m/s have been preferred for drying of green peas (Pardeshi *et al.*, 2009).

Relation between drying rate vs. average moisture content

The drying rate (Chakraverty, 2000) was computed as:

$$\frac{dm}{dt} = \frac{M_i - M_{(i+1)}}{t_{(i+1)} - t_i}$$

Where, dm/dt = drying rate at moisture i (% db moisture loss per min)

M_i =Moisture content, kg per kg dry matter at time t_i

$M_{(i+1)}$ = Moisture content, kg per kg dry matter at time $t_{(i+1)}$

The relationship between drying rates and average moisture contents during drying process are shown in Fig. 3 for forced air solar drying and forced air shade drying. From this figure, it is evident that the forced air solar drying of wheatgrass exhibited falling rate period as first (III) and second (IV) without assuming any period for initial adjustment (I). The forced air shade drying exhibited falling rate period as first (III) and second (IV) besides assuming some period for initial adjustment (I). The critical moisture content (CMC) was observed to be 3.5 and 4.0 kg per dry matter, respectively for forced air solar drying and forced air shade drying. The average drying rates were recorded to be 0.0370, 0.0051, 0.0344, 0.0164 and 0.0113 kg per kg dry matter per min, respectively for sun drying, shade drying, forced air solar drying, solar drying with natural draft and forced air shade drying. The lowest drying rate in case of shade drying was mainly due to low drying temperature and absence of flowing air. This was major cause for prolonged drying time (1110 min) required and highest EMC (0.0711 kg per kg dry matter) in case of shade drying. The higher drying rates were observed in case of sun drying due to exposure of drying material to free air and higher drying temperature.

The plots of moisture ratio versus drying time are shown in Fig. 4. The exponential decay of moisture ratio with drying time was observed in all the cases. The time of half response i.e., time (t) required to reach MR=0.5 (Table 3) was found to be merely 15 min for wheatgrass dried using forced air solar drying and 100 min for wheatgrass dried using forced air shade drying.

Preparation of powder from dried wheatgrass: The dried wheatgrass sample was taken equivalent to half depth of the grinding bowl. The grinder with sample was kept inside the refrigerator for 10 to 15 min in order to lower down its temperature. Then grinding was done for 10 to 15 s. Further increase in grinding duration indicated little heating of grinding sample. Therefore, grinding was restricted for 10-15 s. Further, the rest for 10 to 15 min was rendered so as to cool down the grinder and sample. This process was repeated for 10-12 times or till the complete grinding was ensured. The ground matter was sieved through fine mesh (106 µ). The 60 to 70 % fine powder was obtained from a sample of dried wheatgrass. The samples of fine powder were packed in airtight 200 g HDPE bags.

The final moisture content in wheatgrass powder varied mainly due to ability of drying process to withdraw the moisture from wheatgrass. From Table 2, it could be seen that the final moisture was higher (0.064 to 0.076 kg per kg dry matter) in samples dried by shade drying and solar drying with natural draft, as these methods could not withdraw moisture to very low level, thus these were reported to be EMC of the dried wheatgrass. The drying methods like forced air solar drying, forced air shade drying and sun drying could reduce moisture to considerably lower levels i.e., from 0.0281 to 0.0462 kg per kg dry matter; the lowest one by using forced air solar drying (0.0281 kg per kg dry matter).

Proximate composition of tender wheatgrass: The major loss in fat content was observed in case of samples dried by forced air solar drying and forced air shade drying. In other cases, the fat content was found to be retained considerably (0.87 to 0.99 g per 100 g dry matter).

The ash content and protein content were also not affected by drying processes and ranged between 10.62 to 12.57 and 35.12 to 38.67 g per 100 g dry matter, respectively.

The carbohydrate + fibre contents were determined by difference method and there was a little variation in it for samples dried by different methods under experimentation.

The major loss of ash content in dried wheatgrass powder as compared to fresh wheatgrass was might be due to loss of 30-40 % course material during sieving.

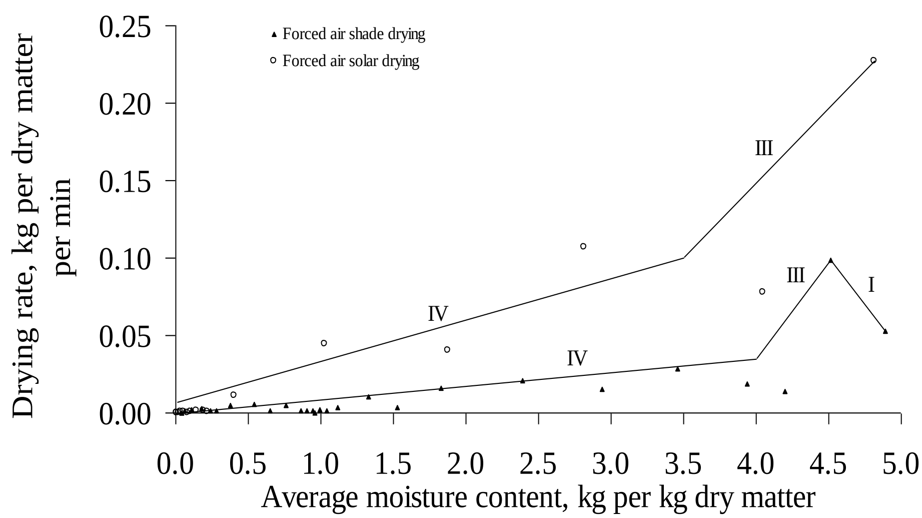

Fig 3: Variation in drying rates with average moisture content for drying of wheatgrass

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The increase in fat, protein and carbohydrates + fibre contents in fine powder as compared to fresh wheatgrass may be due to the fact that the major portion of these constitutes might be retained in the fine powder.

The major constitute i.e., chlorophyll content in fresh wheatgrass was 0.042 g, while it was almost similar in dried powder in all the cases and ranged between 0.127 to 0.137 g per 100 g dry matter. From the Table 2 and 4, it was clear that solar drying with natural draft subjected the drying sample at higher average temperature (50.9 °C) for considerably longer drying time (480 min), thereby hampered the chlorophyll content (0.127 g per 100 g dry matter) of the resultant dried and ground wheatgrass sample. The shade drying (average temperature 32.9 °C) and shade drying with forced air (average temperature 33.6 °C) resulted into dried wheatgrass samples having 0.137 and 0.135 g chlorophyll per 100 g dry matter, respectively. Despite of higher drying temperatures in case of open Sun drying (average temperature 42.8 °C) and forced air solar drying (average temperature 43.6 °C), the faster drying rates might be responsible for higher chlorophyll content (0.133 and 0.134 g chlorophyll per g dry matter, respectively) in dried wheatgrass samples. The sun drying required lesser drying time however the direct exposure to solar radiation might have affected chlorophyll content of dried material as compared to that by forced air solar drying. Thus, the lower possible temperature (avoiding direct exposure to sun rays) is advisable in case of drying of tender wheatgrass.

Mathematical modeling of drying behaviour: The empirical equation, $\ln(MR) = \exp^{(-kt^n)}$, proposed by Page (1949) was tried to fit to the experimental data of drying material dried using different drying methods as sun drying, shade drying, forced air solar drying, solar drying with natural draft and forced air shade drying.

The values of constants 'k' and 'n' in above equations are listed in Table 5. The equations were found to represent the experimental data considerably (Fig. 4) on the basis of coefficient of determination (R^2) which is more than 0.94, in each case.

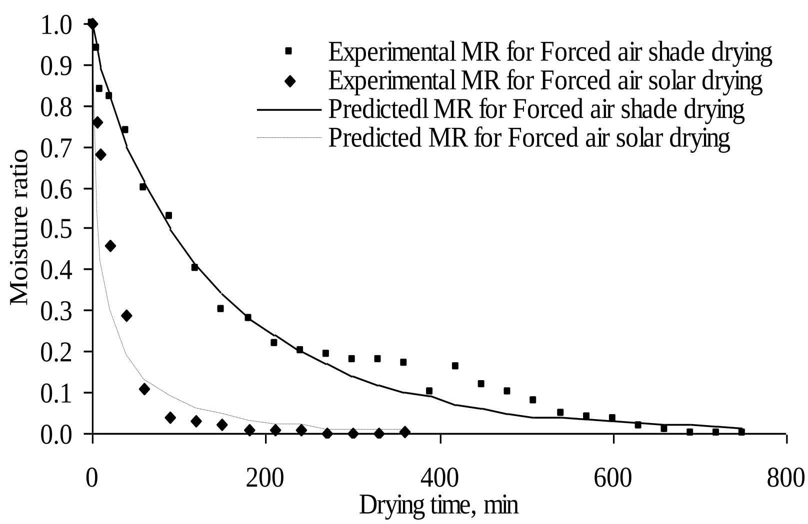

Fig 4: Variation in moisture ratio with drying time for drying of wheatgrass

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Table 3: Time of half response with respect to different drying methods used for wheatgrass drying

Drying method	**Sun dryin**	**Shade drying**	**Forced air sol drying**	**Solar drying with natural draft**	**Forced air shad drying**
Time of half response, min	50	200	15	90	100

Table 4: Proximate composition (g per 100 g dry matter) of wheatgrass powder samples

Sl. No	**Composition**	**Powder of wheatgrass prepared after drying by**				
		Sun drying	**Shade drying**	**Forced air solar drying**	**Solar drying with natural draft**	**Forced air shade drying**
1.	Moisture content	4.36	7.65	2.81	6.39	3.94
2.	Fat	0.99	0.87	0.71	0.88	0.82
3.	Protein	35.12	36.12	37.41	37.17	38.67
4.	Ash	10.63	12.57	12.49	10.83	11.73
5.	Carbo+Fibre	53.13	50.32	49.26	51.00	48.65
6.	Chlorophyll	0.133	0.137	0.134	0.127	0.135

Table 5: The values of constant in Page's equation and coefficient of determination

Sl. No.	**Drying method**	**k**	**n**	$\mathbf{R^2}$
1	Sun drying	0.006825	1.2473	0.940
2	Shade drying	0.000892	1.2982	0.984
3	Forced air solar drying	0.066271	0.8120	0.979
4	Solar drying with natural draft	0.014087	0.8928	0.975
5	Forced air shade drying	0.014854	0.8525	0.938

Conclusions

The wheatgrass could be well grown in multi shelves rack yielding 1.43 g fresh wheatgrass per g bold wheat seeds. The forced air solar drying followed by forced air shade drying was found to be suitable method to dry the fresh wheatgrass. Using forced air solar dryer, the wheatgrass, could be dried at average drying temperature of 42-43 °C in 270 min, with desirable effects like lower drying time and higher chlorophyll content. The forced air shade drying at 33.6 °C could dry the wheatgrass in 720 min. The initial moisture content of the sample was 5.02 kg per kg dry matter, targeted moisture content was 0.05 kg per kg dry matter, air velocity used was 0.17 m/s and spreading density of wheatgrass was 0.25 to 0.30 kg/m^2 in both the cases. Time of half response for forced air solar drying and forced air shade drying of wheatgrass were estimated to be 15 and 100 min, respectively. The dried wheatgrass could be ground to the fine quality powder by cooling the dried wheatgrass at refrigerator condition followed by grinding in domestic mixer-cum-grinder. Wheatgrass drying carried out by different methods could be predicted with help of Page's equation with considerably high coefficient of determination i.e., 0.94 to 0.98.

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