POLJOPRIVREDNA TEHNIKA
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Godina XXXVII
Broj 2, decembar 2012.
Strane: 25 - 30

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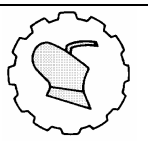

UDK: 664.933

Originalni naučni rad
Original scientific paper

STUDY ON TRANSPIRATION OF CHICKPEA SPROUTS (*Cicer arietinum* L.) IN CLOSED MODIFIED ATMOSPHERIC SYSTEM

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Abstract: Transpiration is an important physiological process that affects the quality attributes of chickpea sprouts, such as package weight, color, appearance and texture. A loss in weight of only 5% may cause fresh produce to lose freshness and appear wilted and it is an important parameter to be considered while designing appropriate packaging system. To measure the transpiration rate an experimental setup was developed to monitor the mass loss of chickpea sprouts at different atmospheric temperatures (5, 10 and 15°C) and 75, 85 and 95% relative humidity. Mass loss of fresh packed chickpea sprouts was measured and transpiration rates were calculated for each treatment. Transpiration rate of sprouts varied from 1.85 $mg \cdot cm^{-2} \cdot h^{-1}$ to 2.15 $mg \cdot cm^{-2} \cdot h^{-1}$ under all the combinations of temperature and humidity tested.

Key words: *diffusion, moisture loss, packaging, storage, transpiration rate*

INTRODUCTION

The moisture accumulation under MAP depends upon transpiration rate [9]. It is influenced by several factors such as surface area, respiration rate, temperature, and humidity and air movement. Other than these factors, crop biological variables like physical properties of the skin, air film resistance, respiration heat generation, temperature distribution inside the produce etc. have also been analyzed as affecting the transpiration rate [13]. These biological variables are complex and difficult to measure, but the transpiration could be easily accessed by the measuring of mass loss of produce

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and the difference between partial pressure of water vapor at the produce surface and the environment [8].

During post-harvest handling and storage, chickpea sprouts lose moisture by the transpiration process [2]. Deterioration, such as shriveling or impaired flavor, may result if moisture loss is high. In order to minimize losses due to transpiration, and thereby increase both market quality and shelf life, sprouts must be stored in a controlled temperature and humidity environment such as MAP [4]. In addition to proper storage conditions, moisture-proof films can be used during commodity packaging to significantly reduce transpiration and extend storage life [1]. Properly designed and operated storage system (MAP) facilities will extend the storage life of commodities by providing a suitable atmospheric condition, which reduces moisture loss and decreases respiratory activity [11]. A thorough knowledge of the transpiration processes will allow both the designer and producer to achieve optimum storage conditions [9].

The objective of this study was to measure the transpiration rate of sprout samples under different temperature and relative humidity condition.

MATERIALS AND METHODS

Plant Material

Chickpea seeds (*Cicer arietinum* L.) var. PBG-5 was collected in local farm in autumn at full maturity. Samples were uniformly treated with Ca $(OCl)_2$ @ 20,000 ppm for 15 min for sterilization and soaked in clean water (1: 3, w/v) for 12 h overnight at ambient room temperature. The washed seeds (soaked) were then shifted to clean sterile muslin cloth and placed in dark at ambient temperature for sprout growth. After 48 h the sprouts were harvested for experimentation.

Experimental Setup

The experimental setup consisted of one test glass container located within a large insulated, controlled atmospheric chamber with internal air temperature controlled at test levels by a refrigeration unit. Humidity within the test containers was independently controlled by using saturated salts solutions of sodium chloride, potassium chloride and potassium nitrate giving desired RH [10]. Salt solution was placed at the bottom of the container. This setup was found to maintain a constant relative humidity throughout the experimental run. An electronic balance was located at the top of the container to record the change in mass of the packed sprouts during the storage period. The mass of each sample could be measured without opening the test containers. Temperature and RH inside the container was monitored continuously using a data logger (Humidiprobe, Pico Tech, UK).

Transpiration measurement of sprout

The transpiration rate of chickpea sprouts was determined as per the weight loss technique adopted by [7]. The samples (150±1g) were equilibrated at experimental conditions for two hours before the start of the experiment and hanged independently

inside the set-up using cotton string. Caps were placed on the container and sealed with grease. The sealed container was placed inside walk-in type cold room maintained at set temperature and RH. The change in mass of the sample at regular intervals was recorded by electronic balance (Precisa 205A SCS, Dietikan, Switzerland) using the string arrangement. The entire set of experiments for particular temperature was replicated thrice. The fresh and graded chickpea sprouts were taken to keep the size and quality during the experiment. Sprouts transpiration rate, TR ($mg \cdot cm^{-2} \cdot h^{-1}$) was then calculated from the changes in sprouts mass over time and expressed by dividing the mass loss with respect to its area. The mathematical expression for transpiration rate (TR) is as bellow:

$$TR = -\frac{1}{A_{Sp}} \times \frac{dm}{dt} \tag{1}$$

With:

$$A_{Sp} = A_{Seed} + A_{Hypocotyl} \tag{2}$$

Where:

TR	$[mg \cdot cm^{-2} \cdot h^{-1}]$	- transpiration rate,
A_{Sp}	$[mm^2]$	- total surface area of seed sprout,
A_{Seed}	$[mm^2]$	- surface area of seed,
$A_{Hypocotyl}$	$[mm^2]$	- surface area of sprout,
dm	[mg]	- differential change in mass,
dt	[h]	- differential change in time,
Dg	[mm]	- geometric mean diameter,
L	[mm]	- length of seed,
W	[mm]	- width of seed,
r	[mm]	- radius of hypocotyl,
s	[mm]	- side length of hypocotyl,
π	[3.14]	- constant.

$A_{seed} = \pi (Dg)^2$; and $Dg = (L\ W^2)^{1/3}$ calculated from the relationship given by Baryeh [14]. Where, S is the surface area of the sprouts, Dg is geometric mean diameter, linear dimensions of fruits as length (L) and width (W) were measured by using a digital caliper gauge with a sensitivity of 0.01 mm. and;

$A_{Hypocotyl} = \pi r^2 + \pi rs$; calculated by assuming hypocotyls surface area identical to standard cone surface area. Where, r is radius of hypocotyls and s is side length of hypocotyls. To reduce the variability in collected data, transpiration rate was measured on 25 sprouts weighing between 20 and 50 mg and the values were averaged.

RESULTS AND DISCUSSION

Transpiration Rate (TR) of Chickpea Sprouts

Transpiration rate was calculated by fitting the experimental data to Eq. (1) for each of the experimental conditions tested. The detail observation for transpiration rate of chickpea sprouts is given in Tab. 1. It was observed that the transpiration rate

was 1.84, 1.34 and 1.17 mg·cm^{-2}·h^{-1} at 75, 85 and 95% RH respectivily at 5°C; 1.97, 1.46 and 1.25 mg·cm^{-2}·h^{-1} respectivily at 75, 85 and 95% RH at 10°C and 2.15, 1.98, 1.43 mg·cm^{-2}·h^{-1} respectivily at 75, 85 and 95% RH at 15°C with an average surface area of 160.52 cm^2.

These values are higher than other products as reported by Kang and Lee [6] for cut onion (transpiration rate: 0.448 g·kg^{-1}·h^{-1}) at 10°C and 82% RH in normal air. Tomato fruits (TR: 0.1 mg·cm^{-2}·h^{-1}) at the same vapor pressure deficit of 0.45 kPa as reported by [7, 12]. This is because chickpea sprouts do not have a protective skin that leads to higher moisture loss due to increasing respiration during sprout growth and development.

The effect of temperature and humidity on TR of chickpea sprouts was found to be significant at 95% significant level. This analysis showed that, in the range of conditions studied, both temperature and humidity were the influential variables [3]. The effect of temperature and humidity on TR was more pronounced. The interactive effects between temperatures were also significant, with the effect of temperature on TR, increasing with increasing temperature. The results stress the importance of maintaining proper in-pack humidity levels as well as storage temperature in order to extend the shelf life of chickpea sprouts. In-package temperature of 10°C and 75% relative humidity was found to be optimum for fresh chickpea sprouts.

Table 1. Transpiration rate of chickpea sprouts at different temperature and relative humidity condition

Temperature (°C)	Relative Humidity (%)	*Transpiration Rate (mg·cm^{-2}·h^{-1})
5 ± 1	75 ± 2	1.85
	85 ± 2	1.34
	95 ± 2	1.17
10 ± 1	75 ± 2	1.97
	85 ± 2	1.46
	95 ± 2	1.25
15 ± 1	75 ± 2	2.15
	85 ± 2	1.98
	95 ± 2	1.43

** Statistically significant (Temp, RH and TempXRH) at P ≤ 0.05 and average of means of three replications.*

CONCLUSIONS

The transpiration rate of chickpea sprout sample was significantly affected by temperature as well as relative humidity. The effect of increasing temperature on TR increases with increasing temperature and the effect of humidity on TR increases with decreasing transpiration rate of chickpea sprouts. At the highest humidity, temperature has little effect on TR whereas the effect was more pronounced at 75% RH.

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ISPITIVANJE TRANSPIRACIJE KLICA LEBLEBIJA (*Cicer arietinum* L.) U ZATVORENOM MODIFIKOVANOM ATMOSVERSKOM SISTEMU

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Sažetak: Transpiracija je značajan fiziološki proces koji utiče na osobine kvaliteta klica leblebija, kao što su težina pakovanja, boja, izgled i tekstura. Smanjenje težine od samo 5% može da izazove gubitak svežine svežeg proizvoda i pojavu uvenuća, što je važan parametar, koji se uzima u razmatranje pri projektovanju odgovarajućeg sistema pakovanja. Za merenje intenziteta transpiracije razvijen je eksperimentalni uređaj za praćenje gubitka mase klica leblebija pri različitim temperaturama (5, 10 i 15°C) i relativnim vlažnostima (75, 85 i 95%) vazduha. Meren je gubitak mase sveže upakovanih klica leblebija i izračunavani su intenziteti transpiracije za svaki tretman. Intenzitet transpiracije klica je varirao od 1.85 $mg \cdot cm^{-2} \cdot h^{-1}$ do 2.15 $mg \cdot cm^{-2} \cdot h^{-1}$ pri svim ispitivanim kombinacijama temperature i vlažnosti.

Ključne reči: *difuzija, gubitak vlage, pakovanje, skladištenje, transpiracija*

Datum prijema rukopisa: *Paper submitted:*	09.08.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	01.09.2012.
Datum prihvatanja rada: *Paper accepted:*	11.09.2012.