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INFORMATION PROCESSING IN AGRICULTURE XXX (2017) XXX–XXX

journal homepage: www.elsevier.com/locate/inpa

The effect of dynamic loading on abrasion of mulberry fruit using digital image analysis

Fatemeh Afsharnia [a,*], *Saman Abdanan Mehdizadeh* [b], *Mahmoud Ghaseminejad* [a], *Mokhtar Heidari* [c]

[a] *Department of Agricultural Machinery Engineering, Ramin Agriculture and Natural Resources University of Khuzestan, Iran*
[b] *Department of Mechanics of Biosystems Engineering, Ramin Agriculture and Natural Resources University of Khuzestan, Iran*
[c] *Department of Horticultural Science, Ramin Agriculture and Natural Resources University of Khuzestan, Iran*

A R T I C L E I N F O

Article history:
Received 5 April 2017
Received in revised form
12 July 2017
Accepted 12 July 2017
Available online xxxx

Keywords:
Abrasion
Dynamic loading
Postharvest quality
Mulberry

A B S T R A C T

The quality of fruits can be reduced due to some damages and impacts which occur during harvesting. One of the most important mechanical damages that can reduce the quality of ripe fruit quality is abrasion damage. This study focused on the effect of dynamic loading based on customary harvesting method on mulberry fruit properties. To this end, different maturity stage and storage regimes were considered. Color quality parameters, firmness, total soluble solid (TSS), total anthocyanins content (TAC) and abrasion area were the measured factors. The results revealed that none of the surveyed factors were stable during the experiment. The lightness (L^*), redness (a^*), yellowness (b^*), C^* value, firmness, TSS and TAC of immature and mature mulberry decreased during storage. The value of a^*, b^* and C^* increased as dropping height increased. However, L^* value, firmness, TSS and TAC of mulberry fruit decreased at both maturity stages (immature and mature mulberry). Moreover, abrasion area increased at immature and mature mulberries by increasing the dropping height and storage time.

1. Introduction

Protection of fruits against mechanical damage is one of the major concerns of berry producers in the field in order to conserve their quality during harvesting. That is to say that farmers' profit depends on fruits quality: the lower mechanical damages, the more they benefit. Combination of attributes or properties of fruit and vegetables are of great importance for consumption [1]. Short shelf-life is considered as the main postharvest problem of these kinds of fruits, especially for mulberry fruit that is one of the most important soft fruits. Lack of firm texture in most soft fruits, even when freshly picked, is of great importance during the handling [2]. Black mulberry (Morusnigra) not only is known for its nutritional qualities and its flavor, but also for its traditional use in natural medicine, because of having high content of active therapeutic compounds. For instance, the fruit has been used for the treatment of mouth, tongue, and throat inflammations [3]. As well, mulberry fruit is a good source of several phytonutrients and contains high amounts of total phenolics, total flavonoids, and ascorbic acid. Additionally, this fruit has a pleasant taste with a slightly acidic flavor and an attractive dark red color [4,5]. The harvested fruits can be eaten raw, dried, or processed.

* Corresponding author.
E-mail address: phd.afsharnia@ramin.ac.ir (F. Afsharnia).

Peer review under responsibility of China Agricultural University.
http://dx.doi.org/10.1016/j.inpa.2017.07.003
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Nomenclature

List of symbols

TSS	total soluble solid (°Brix)
TAC	total anthocyanins content (mg/100 ml)
L^*	indicator shows lightness on a range of 0–100
a^*	represents the red–green (–)
b^*	represents the blue–yellow (–)
C^*	chroma

The total production of black mulberry (Morus alba. Var.nigra) of Iran was about 187,000 tons in 2015 [6]. Nowadays, the mulberry fruits are often harvested by spreading a sheet on the ground and shaking the branches [7]. The energy of mechanical sources, generated during harvest and distribution, can be transferred to the fruit. Its tissue absorbed and dissipated this energy; therefore, part of this energy cannot create damage. Fruit tissue damage relies on the type, severity and duration of energy transfer [8].

Abrasion damage can occur at any time during harvesting and postharvest handling. Researchers have also demonstrated that occurrence of abrasion damage on fruits leads to inking, staining or skin discoloration [9]. Although these dark or brown spots or stripes on the fruit surface are external, superficial, and restricted to the skin surface, they cause market rejection as well as financial loss to the grower. Meanwhile, the severe problems increase due to mechanical damage which is affective on the trade of these products. The evidence of mechanical damage such as bruise, cuts, puncture, split and abrasion significantly decreases economic value of fresh produce due downgrading or rejection of the appearance quality by the consumer [10,11]. In addition, acceleration of physiological processes as a consequence of mechanical damage leads to senescence, spoilage and loss of nutritional value.

Given these substantial losses and potential gains in developing measures to reduce the problem, it is important to have reliable methods to measure, analyze and detect abrasion damage. Despite the economic importance of abrasion damage as a major quality problem during harvest of fresh horticultural produce, there is currently no study on this subject. The objective of this paper was to determine abrasion of mulberry according to several conditions (drop height, storage regimes and maturity stages) by digital image analysis.

2. Material and methods

2.1. Sample preparation

All the experiments were carried out with "*Morus alba* var *nigra*"mulberry fruits harvested at two maturity stages (immature and mature) from the area surrounding Ramin agriculture and natural resources University, Mollasani, Khouzestan, Iran in June 2016, and verified by the Department of Botany. The mulberry fruits were carefully hand-picked at the orchard, placed in plastic container and were transferred to laboratory. This procedure was followed in order to minimize any abrasion that may be caused by transporting the mulberries. Extremely large or small mulberries were excluded. After careful transportation to the laboratory, the mulberries were inspected again to ensure that they were uniform and non-damaged. They were stored at 3 °C and high RH before further experiments.

The medium height mulberry trees were about 3 ms at the orchard. The mulberries were harvested by shaking the trees and collecting the mulberries on sheets placed beneath the trees. Since, mulberry fruits are susceptible to scuffs, abrasions, shrinkage, and resulting decay, dynamic loading experiments were performed at three heights (0, 1.5 and 3 ms) for abrasion measurement in an orchard simulated ambiance. The selected heights were according to total height and half height of mulberry trees.

Three storage regimes were considered at 3 °C in the first, third and seventh days. According to the two levels of maturity, three levels of height and three levels of storage regimes for assessing abrasion, fruits were divided into 18 groups. For each treatment, 50 g mulberries were selected, so that every sample was used only once.

2.2. Analytical methods

The fruits were mashed in a juicer (MK-8710, National, Japan). Then, the fresh juice was filtered using filter paper and subjected to physicochemical analysis. Three replications were run for each analysis. The following parameters were measured: soluble solid content (TSS) and total anthocyanin content (TAC).

2.2.1. Total soluble solid (TSS) content measurement

The soluble-solids content of the juice samples was measured by an Abbe refractometer (Atagoco. ltd, Tokyo, Japan) at 20 °C and expressed in °Brix. The distilled water was used to calibrate the refractometer.

2.2.2. Total anthocyanins content (TAC)

Total anthocyanins content of mature mulberry juice was determined by the pH differential method using two buffer systems: potassium chloride buffer, pH 1.0 (0.025 M), and sodium acetate buffer, pH 4.5 (0.4 M) [12,13]. Briefly, 0.4 mL of mature mulberry juice sample was mixed with 3.6 mL of corresponding buffers and read against water as a blank at 510 and 700 nm. Absorbance (A) was calculated as:

$$A = (A_{510} - A_{700})pH_{1.0} - (A_{510} - A_{700})pH_{4.5} \quad (2)$$

The total anthocyanin content of the samples (mg cyanidin-3-glucoside/100 mL of mulberry juice) was calculated by following equation:

Please cite this article in press as: Afsharnia F et al. The effect of dynamic loading on abrasion of mulberry fruit using digital image analysis. Info Proc Agri (2017), http://dx.doi.org/10.1016/j.inpa.2017.07.003