

# The harvest season changes the organoleptic properties of onion during storage

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**ABSTRACT**

**Aims:** The objective was to determine the influence of the onion harvest time "Baia Periforme" on post-harvest quality of the bulbs during storage.

**Study design:** The experiment was conducted in a randomized block design with three treatments, six replicates with two bulbs each.

**Place and Duration of Study:** Departamento de Fitotecnia, Universidade Federal de Viçosa, between June 2017 and July 2018.

**Methodology:** Seedlings, 20 days old, were transplanted into 20 cm spacing between rows and 10 cm between plants. The bulbs were harvested 120 days after transplanting with manual tipping of the pseudo-stem (T1), with 50 (T2) or 75% (T3) of the bulbs popped. The soluble sugars (SS), non-reducing sugars (NRS), reducing sugars (RS), total soluble solids (TSS), titratable acidity of phenolic compounds and alinase activity was determined every 30 days for 90 days.

**Results:** The content of SS, TSS, phenolic compounds and alinase activity increased in the onions of T2, resulting in more sweet and pungent bulbs due to the higher content of acidity and phenolic compounds.

**Conclusion:** The post-harvest quality of onion bulbs "Baia Periforme" was maintained when they were harvested with 50% of bulbs popped.

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*Keywords: Allium cepa L., alinase, sugars, storage, quality.*

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### 1. INTRODUCTION

Onions are the third most important vegetable crop in the world economy [1]. One hundred and seventy-five countries grow onions. The latest information available from United Nations Food and Agriculture Organization [2] the onion worldwide production is 64 million tons from 4 million ha. The bulb is used as a seasoning for its characteristic pungent taste and color [3], due to organosulfur compounds and flavonoids, respectively [4,5]. Onion has glucose (reducing sugar), sucrose (non-reducing sugar) and other oligosaccharides [6] also influence the perception of mildly sweet onion flavor [7]. These characteristics depend on the plant variety, the environmental conditions during the growing season, ripening and storage [8]. Curing is also a key factor in maintaining the onion bulbs quality. The cure reduce moisture by allowing skin color changes and volatile sulfur compounds to enhance aroma and reduce bulb susceptibility to microorganisms, characteristics that change according to the genotype). The cure can be natural (done in the field, for a period of three to ten days, depending on the weather) or artificially (fans with natural or heated air are used) [9].

The morphology of the onion bulb is composed of scales ordered according to chronological age; the internal scales are younger and the external scales are older [10]. An onion bulb at physiological maturity is formed by one to three dry skins that surround thin, sequential outer scales. These, enclosing several internal and fleshy scales [10,11].

Some commercial varieties of onion have large variations in maturation due to factors ranging from asynchronous growth and seed development to photoperiod requirements [8]. This results in crops with plants at different stages, making it difficult to determine the harvesting time and reducing bulb quality during storage [9]. The quality of the onion bulbs is evaluated basically by the color of the bulb and the contents of sugars, organic acids and phenolic compounds

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34 that confer characteristic flavor, aroma and color [10,9,11]. These quality characteristics are influenced by the harvest  
35 period.

36 Harvesting of onion bulbs is performed when the pseudo-stems of the plant, called a popping, occurs [12]. The  
37 post-harvest quality of onion bulbs is maintained when the harvest occurs with 50 to 80% of the popped bulbs [13].  
38 Manual popping can induce maturation, homogenize the age of the bulbs and favor the quality and maintenance of the  
39 bulbs during storage [8]. The prolongation of onions post-harvest is of great importance in the onion industry. Onion bulbs  
40 are live products that respire during storage and use carbohydrates and other constituents as respiration substrates, and  
41 the bulbs eventually become senescent and deteriorate. Storage temperature influences metabolic turnover in respiration.  
42 However, rooting, sprouting and disease development can also influence respiration and can lead to considerable food  
43 losses and wastage [13] if bulbs are not sold before high losses occur. Respiratory rate, and hence post-harvest quality  
44 maintenance and loss reduction, will depend on the stage at which the bulbs were harvested [14].

45 The objective was to determine the onion harvest point "Baia Periforme" and the influence on post-harvest quality  
46 of the bulbs during storage.

## 47 48 49 **2. MATERIAL AND METHODS**

### 50 51 **2.1. Characterization of experimental area, harvest and cure**

52 Seed onion "Baia Periforme" were acquired in Isla<sup>®</sup> company (Isla sementes Ltda., Porto Alegre, Rio Grande do  
53 Sul, Brazil) and sown in trays with 200 cells filled with Bioplant<sup>®</sup> substrate (Bioplant Agrícola Ltda., Ponte Nova, Minas  
54 Gerais, Brazil). The seedlings, 30 days after sowing, were transplants for beds (1 x 10 m) spaced 20 cm between row and  
55 10 cm between plants. Fertilization and cultural treatments were carried out according to the need and recommendation of  
56 the crop [15]. The bulbs were harvested by manual tipping of the pseudo-stem (T1), with 50 (T2) or 75% (T3) of the bulbs  
57 popped. The harvested bulbs were placed in airy sheds for 4 days for curing. The cured bulbs were transported to the  
58 laboratory, stored at room temperature and evaluated at 0, 30, 60 and 90 days of storage.

### 59 60 **2.2. Avaliations**

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62 **Total soluble (TSS) and reducing sugars (RS)**- five grams fresh tubers were weighed and 80% ethanol at 65 °C was  
63 added. Samples were ground and homogenized in polytron (IKA<sup>®</sup> Ultra turras T25 digital) and centrifuged twice for 10  
64 minutes at 2000 g. The filtrate volume was standardized to 20 mL. An extract containing two hundred and fifty microliters  
65 of sample, 250 ml of 5% phenol and 1.25 mL of concentrated H<sub>2</sub>SO<sub>4</sub> was prepared, vortexed and placed in a thermostatic  
66 bath at 30 °C for 20 min. The TSS content was determined by spectrophotometry at 490 nm [16]. Reducing sugars (RS)  
67 were determined using the Somogy-Nelson method using 1% glucose as standard [17]. Non-reducing sugars were  
68 obtained by difference between the TSS and RS.

69 **Activity alinase**- six bulbs without surface film was heated in microwave at high power for three minutes for denaturation  
70 and enzyme blank determinant. Five grams of heated or undamaged bulbs and 5 mL of 0.5% trichloroacetic acid were  
71 added. The extract formed was stirred for one hour, filtered on Büchner funnel and the volume completed to 100 mL with  
72 distilled water. A solution containing the extract and 2,4-dinitrophenylhydrazine to 0.0125% dissolved in 2M HCl was  
73 incubated in thermostated bath at 37 °C for 10 min. Five milliliters of 0.6 M NaOH was added and the alinase activity was  
74 determined by spectrophotometry at 420 nm using pyruvic acid at 2 µmol mL<sup>-1</sup> as standard and distilled water as white.  
75 Alliinase activity was calculated by the difference between the values of the materials heated or not and the results  
76 expressed as micromoles of pyruvic acid per gram of onion [18].

77 **Titrate acidity**- ten grams of ground bulb were diluted in distilled water and titrated with 0.05 N NaOH. The results  
78 were expressed as grams of pyruvic acid 100 g<sup>-1</sup> of pulp [19].

79 **Total soluble solids (TSS)**- the TSS were determined in digital refractometer and the results expressed in °Brix.

80 **Total phenolic compounds in peel**- fifty grams of peel bulbs were macerated in a mortar and pestle with 10 ml of  
81 methanol and centrifuged. A solution containing 1 ml of homogenate, 5 ml of Folin-Denis reagent and 5 ml of 10%  
82 NaHCO<sub>3</sub> (anhydrous) was stirred and left to stand for 1 hour. The solution was filtered, and the phenolic compounds  
83 determined by spectrophotometry at 700 nm using D-catechin as standard [20].

### 84 85 **2.3. Experimental design and data analysis**

86 The experiment was conducted in a randomized block design with three treatments, six replicates with two bulbs  
87 each. The data were submitted to analysis of variance using the statistical software SAEG 9.1 – Sistema de Análises  
88 Estatísticas e Genética [21] and when significant was held descriptive analysis of them.

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## 2. RESULTS AND DISCUSSION

The sugar contents differed with the harvest period. The total soluble sugars content (TSS) of T1 reduced during storage and increased in T2 and T3, being abrupt between 60 and 90 days (Figure 1A). Reducing sugar content (RS) increased in the bulbs of all treatments up to the 30th day of storage, remained stable in those of T1 and T2 from 30 to 60 days and decreased from 60 to 90 days (Figure 1B). The reducing sugar content (RS) in the T1 bulbs did not differ during storage and increased in T2 and T3 (Figure 1C). The total soluble solids (TSS) was higher in T2 and T3 bulbs on day 0, day 30 at reduced and increased until the 90th day of storage (Figure 1 D).

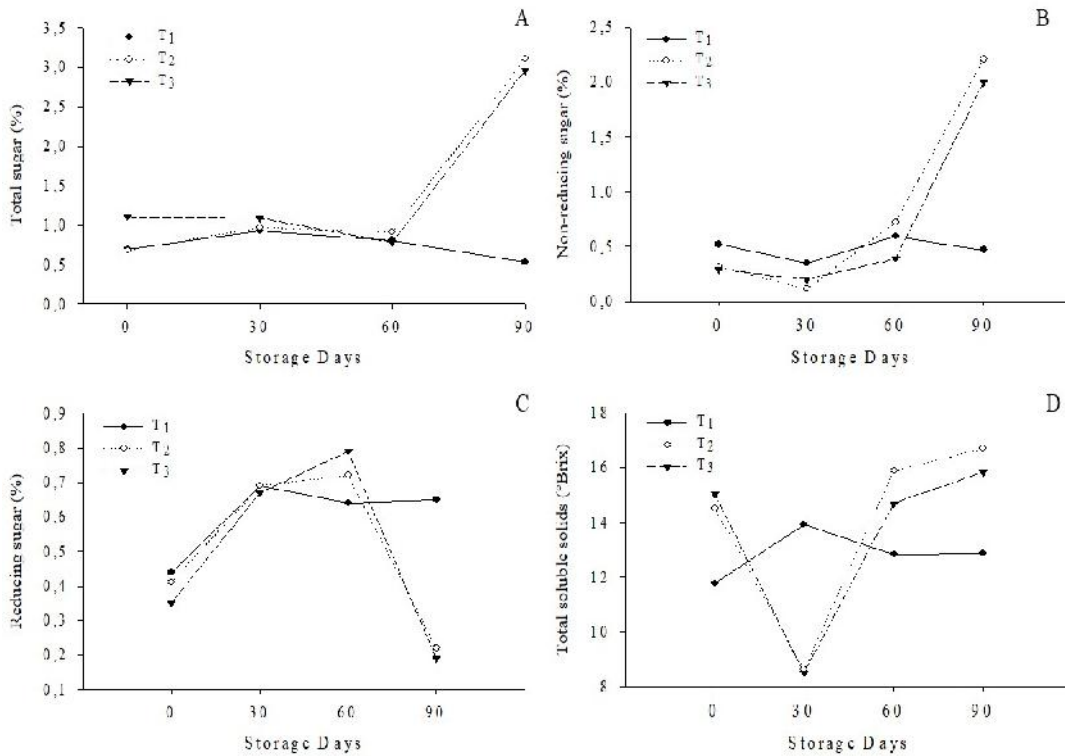


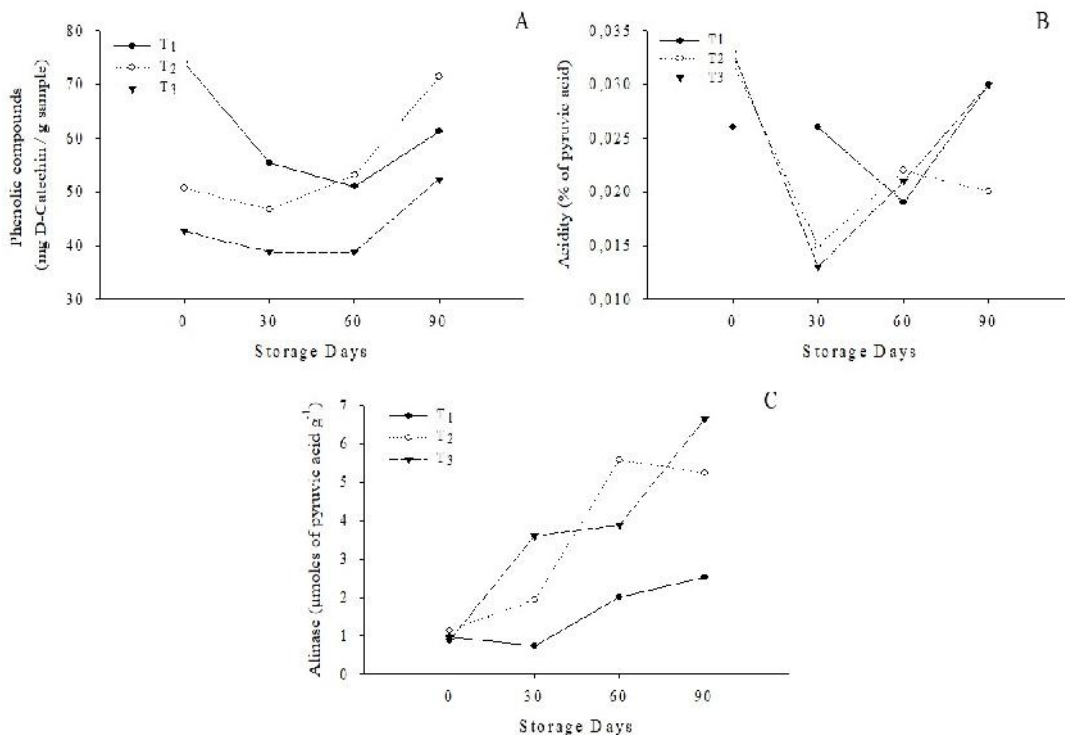
Fig. 1. Total soluble sugars (A), non-reducing (B), reducing (C) and total soluble solids (D) of onions stored for 90 days.

The difference in the sugar content with the harvest period is due to the dynamics of the carbohydrate metabolism during the formation and development of the bulbs [22]. Glucose, fructose, sucrose and fructo-oligosaccharides are the predominant non-structural carbohydrates in onion bulbs [23,22]. These non-structural carbohydrates are transported and accumulated as energy source to be used in cell metabolism, growth and complete plant and bulb formation [24]. Therefore, the variation of the concentration of sugars in the bulbs depends on their stage of development. The sugar concentration in immature bulbs tend to be smaller because they are being consumed for the growth and development of the shoot [25] tends to be higher in mature bulbs [26]. A mature fresh onion bulb contains on average 80-85% moisture and up to 80% dry matter are non-structural carbohydrates [27]. In addition to energy transfer in plants, carbohydrates are also involved in the regulation of gene expression [28]. Starch or any other carbohydrate from the raffinose group were not detected on onions [29]. The reduction in TSS of T1 during storage is due to the increased catabolism of carbohydrates by respiration, due to the stress caused by the manual tipping of the pseudo-stems. Respiratory rate and energy demand increase in injured tissues for the biosynthesis of biopolymers of defense and regeneration [30]. These are synthesized from intermediates of oxidative pathway pentose phosphate carbohydrates and mitochondrial tricarboxylic acid cycle. These pathways are intensified in response to injury and other biotic and abiotic stresses [31] to prevent oxidative damage and regenerate tissues. In addition, the reduction of TSS in the T1 bulbs can be explained by the partial removal of tissues from the leaf base. The content of non-structural sugars is higher in foliar base tissues that reached maximal cell expansion [31,22]. The increase in TSS in T2 and T3, being abrupt between 60 and 90 days can be explained by the fact that the bulbs of these treatments were collected with natural popping, indicating, theoretically, physiological maturity. The accumulation of sugars in this case would serve as an energy source for onion regrowth [29,30,31], explaining the accumulation at the end of storage. Non-structural sugars represent an important carbohydrate

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124 reserve in most onion bulbs and are generally enzymatically hydrolyzed to fructose during the storage period and are  
 125 responsible for the concomitant increase in fructose concentration. Soluble sugars are needed to provide energy for  
 126 sprout growth [6]. However, there are conflicting reports about the fate of sucrose and monosaccharides in whole bulbs  
 127 during storage [32,23]. From the organoleptic point of view, the bulbs harvested at 50 and 75% crack were sweeter during  
 128 storage due to the increase in NRS (sucrose) contents. The NRS is cleaved yielding RS (glucose and fructose), which  
 129 explains the increase in the RS content found in this study to T2 and T3 (Randle, 1992). TSS, NRS and RS are  
 130 responsible for imparting sweet taste and aroma to onion bulbs [33]. However, the variation in sugar levels in onion is not  
 131 clearly elucidated, as it depends on numerous factors such as cultivar, time of release of dormancy and sprouting [6]. The  
 132 highest TSS content on day 0 of onion bulbs harvested at 50 and 75% burst is due to the accumulation of non-structural,  
 133 reducing (glucose and fructose) and non-reducing sugars (sucrose) resulting from the metabolism of pre and post  
 134 carbohydrates [23]. Mature onion bulbs contain 80% non-structural carbohydrates in dry matter [24] because of the longer  
 135 accumulation of sugars by the translocation of photoassimilates [34]. The translocation of photoassimilates to the bulbs is  
 136 a complex process. Before bulbing, the highest percentage of dry matter and soluble solids is found in the aerial part and  
 137 the rest is distributed between the leaf sheath and the stem base [35]. During the bulbing there is cessation of the  
 138 additional growth of new leaves and the development of younger leaves. As a result, the increase in bulb size will depend  
 139 on the transfer of photoassimilates accumulated in the photosynthetic regions of the plant to the sheaths, as well as on  
 140 the hydrolysis of previously accumulated non-structural carbohydrates. Therefore, late harvested bulbs tend to have  
 141 higher concentrations of soluble solids (sugars) to meet the energy demand of cell expansion [34]. Bulbs with higher  
 142 sugar content have higher content of SS, it is this fraction that is non-structural sugars responsible for the characteristic  
 143 taste of onion [20,33]. The TSS content is lower in onion bulbs harvested before popping or green (20% burst) and higher  
 144 in those harvested 50% popping [36], resulting in more bulbs during storage. Late or demanding photoperiod cultivars  
 145 such as `Baia Periforme` tend to have higher soluble solids content [8].

146 The content of phenolic compounds differed with the harvest period, being higher in T1. The phenolic compounds  
 147 reduced in the bulbs of all the treatments until the 30th day of storage and increased until the 90th day (Figure 2A). The  
 148 titratable acidity of T2 and T3 bulbs increased within the first 30 days of storage and did not change in T1. Subsequently  
 149 acidity levels increased in T2 and T3 bulbs at 60 and 90 days, respectively. The acidity of the T1 bulbs increased only  
 150 from the 60 days of storage reaching the same acid values of T3 at 90 days (Figure 2B). Alliinase activity of bulbs  
 151 increased in all treatments and the increase was greater in the T2 and T3 (Figure 2 C).  
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 156 **Fig. 2. Phenolic compounds (A), acidity (B) and enzymatic activity of the alliinase (C) of onions stored for 90 days.**  
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158 The higher content of phenolic compounds in the T1 bulbs is possibly due to the increase of respiration caused by  
 159 the injury during the manual tipping of the pseudo-stems. The increase in the content of phenolic compounds after a  
 160 wound provides additional carbon intermediates for the biosynthesis of defense compounds, healing and antioxidants



[37]. The increase in the concentration of phenolic compounds was also reported after lesion of sugarbeet and carrot roots [38,39,40]. Biotic stress increases the content of phenolic compounds after harvest [41]. The reduction of phenolic compounds with subsequent increase is possibly related to the biosynthesis of flavonoids, mainly quercetin. The non-structural sugars increase in onion bulbs during storage [42,43,44] to provide metabolic energy for flavonoid biosynthesis [45]. The increase in flavonoid content, especially quercetin, at the end of storage is related to formation and brown staining of onion peel [46], breakage of dormancy and budding [45]. High concentrations of phenolic compounds are desirable due to their antioxidant properties [47]. The early increase of acidity or pungency in the T2 and T3 bulbs during storage is associated with an increased content of pyruvic acid catalyzed by alliinase, whose activity also increased. Allinase cleaves S-methyl cysteine sulphoxide, S-allyl cysteine sulphoxide, S-trans-prop-1-enyl cysteine sulphoxide, and S-propyl cysteine sulphoxide to form pyruvate, ammonia and a thiosulfinate [48]. The characteristic taste and odor of fresh onion is due to the degradation of S-methyl cysteine sulphoxide and S-allyl cysteine sulphoxide, respectively. The latter undergoes new reactions, altering the onion's characteristic smell with storage time [49]. During storage, there is greater contact between the substrates present in the cytoplasm and the enzyme allinase found in the vacuole, allowing the formation of a greater number of organosulphur compounds, which are responsible for the taste of the onion, which may indicate the protective effect of the enzyme in the conservation of bulbs [50]. The pungency of the bulbs was classified in the present work as indicated by the VLI Sweet Index [51]. The VLI Sweet Labs indicates that the onions can be classified by the pungency of alliinase activity, which is expressed in mmoles pyruvic acid g<sup>-1</sup>, "very soft" (in mmoles 0-2.9 g<sup>-1</sup>), "(3.0-4.2 μmol g<sup>-1</sup>), "slightly pungent" (4.3-5.5 μmol g<sup>-1</sup>), "pungent" (5.6-6.3 μmol g<sup>-1</sup>), "Strong pungency" (6.4-6.9 μmoles g<sup>-1</sup>), "very strong pungency" (7.0-7.9 μmoles g<sup>-1</sup>) and "pungent" (8.0-10.0 μmoles g<sup>-1</sup>). In the harvest and cure period, the bulbs were classified as very soft. At the end of storage, they were classified as very soft (T1), slightly pungent (T2) and pungent (T3). The importance of the knowledge of the bulb's pungency is in the acceptance of the market, which has preference for "pungent" bulbs [52,53].

### 3. CONCLUSION

Harvesting with 50% of the popped bulbs allows the production of more sweet, pungent bulbs with higher acidity and higher contents of phenolic compounds

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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