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Effects of γ irradiation, temperature and storage time on the status of the glucose, fructose and sucrose in onion bulbs *Allium cepa* L.

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A b s t r a c t. The variations of glucose, fructose and sucrose in onion bulbs irradiated at 0.15 and 0.30 kGy and stored at 4, 10 and 20°C were investigated. Between 5 and 8 weeks glucose increased in concentration and varied between 3 and 3.7 g·100 g^{-1} of fresh weight at these temperatures. The same pattern was observed in the fructose, however, the increase varied between 1.4 and 2.93 g·100 g^{-1} of fresh weight. During the last 15 weeks of storage, the glucose and fructose remained stable, ranging between 1 and 1.5 g·100 g^{-1} of fresh weight. The fructose/glucose ratio was slightly higher in the control bulbs, but in the ionised bulbs, the ratio remained relatively constant. However, the sucrose content remained constant except for a small increase observed after six weeks and was between 0.61 and 1.09 g·100 g^{-1} for the control and 0.30 kGy for the treated bulbs respectively at 10°C, and 0.73, 1.23 and 1.16 g^{-1} ·100 g for the control, 0.15 and 0.30 kGy for the treated bulbs at 20°C, respectively.

K e y w o r d s: glucose, fructose, sucrose, ionisation, storage

INTRODUCTION

The onion bulb as other Alliums is widely used for culinary and medicinal purposes. Besides its remarkable medicinal powers, onion is generally consumed for flavour and nutritive values, which have only been appreciated recently [15]. During harvest, handling, transportation, packaging and storage, onion bulbs are exposed to several treatments, atmospheric conditions and temperatures which can affect their quality and physiological characteristics [2]. The results of these effects could be responsible of several reaction and stresses causing important biochemical changes to bulb tissue [3].

Carbohydrates in onion bulbs account for a major portion of their dry matter, contributing as much as 65 to 80% of the dry weight; the principle components of the non-structural carbohydrates are glucose, fructose, sucrose and the series of fructans (fructosyl polymers) with a degree of polymerisation (DP) up to 12 [5,7,16]. The composition of non-structural carbohydrates has an important implication for the physiology during bulb formation, maturating, dormancy and sprouting of the bulb [5,7,10]. The effect of different storage conditions such as temperature, time and irradiation, on the total of soluble sugars and fructans have not been extensively studied and recent physiological and biochemical studies suggest that it is important to measure carbohydrate levels in onions subjected to different storage treatments and temperatures [2,12].

Several investigations have been carried out throughout the world on the use of ionising radiation for controlling the sprouting of onions [9,11]. The irradiation doses ranging from 0.05 to 0.15 kGy inhibit bulb sprouting, and are more effective when applied during the dormancy period ca. within the six to eight weeks following harvesting [15]. Ionised bulbs can be stored for several months without heavy spoilage, though ionisation and storage can affect changes in the carbohydrates content of onion tissue. However, despite the existence of much data on the commercial quality of irradiated onion bulbs, little information is available on the pattern of the main chemical components such as non-structural carbohydrates during irradiation treatment and long-term storage.

The aim of this investigation was to assess the effects of irradiation and long-term storage on onion bulbs c.v. Rouge Amposta. Two irradiations were used (0.15 and 0.30 kGy) and the treated bulbs were stored at three different temperatures (4, 10 and 20°C) for 24 weeks. The concentration of glucose, fructose and sucrose was then determined every 15 days.

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MATERIAL AND METHODS

Onions

Onion bulbs *Allium cepa* (organic product, free of any pre-harvest chemical treatment) cv. Rouge Amposta freshly harvested (September 2, 1997 and September 5, 1998) and dried in the field during two weeks were obtained from the local market (supplied by Pronatura, M.I.N, Avignon, France). These were sorted for uniformity and the absence of defects and were packed in commercial plastic (PVC) trays of 12 kg and placed at 18°C prior to ionising treatment.

Ionising treatment

Ionising treatment of the onion bulbs was performed at the Commissariat a l'Energie Atomique (CEA) of Cadarache (France) using a ^{60}Co source at a dose of 0.15 and 0.30 kGy at 20°C. The treatment was applied 17 days (September 19, 1997) and 19 days (September 24, 1998) after harvesting.

Storage conditions

Immediately after ionising, the onions were stored at three sets of temperature and a relative humidity: 4°C and 85% RH, 10°C and 80% RH and, ambient condition of 20°C and 65% RH.

Soluble sugars analysis

The glucose, fructose and sucrose content was determined by HPLC [8]. Samples of 5 g of freeze-dried tissue were homogenised in 50 ml of water using a 'Sorvall' blender (Omni-mixer 17220, Newton, USA). The homogenate was then heated for 30 min in a boiling water bath (Haake Inst., Berlin, Germany). After cooling, the homogenate was centrifuged for 15 min at 25 000 x g using a 'Heraeus' centrifuge (Heraeus Sepatech GmbH, Osterode/Harz, Germany) and the supernatant was filtered on a 0.25 µm 'Millipore' filter (Millipore S.A, Molsheim, France).

The sugars were separated by HPLC using a 'Varian' 5000 model (Vista, 5000 series, Les Ulis, France) fitted with a Polyspher CH-CA column (300 x 7.8 mm. Merck, Darmstadt, Germany) set at 80°C with an appropriate guard column (Merck) and a differential refractometer detector (Knauer GmbH, Hegaver, Berlin, Germany). The mobile phase was DDI water at a flow rate of 0.5 ml$\cdot$min^{-1}.

The sugars were identified and quantified by comparison with standards (Sigma ® Co, St-Louis, USA) and each determination was run in triplicate.

Statistical analysis

The experiment was repeated in two successive harvests (1997 and 1998). The data was analysed statistically by determination of the least significant difference (LSD at ρ 0.01) using XLStat. Pro® statistical software (XLStat, Paris, France).

RESULTS

Immediately after the ionising treatment, the glucose content of the treated bulbs slowed down due to the respiration stress induced by ionisation causing the glycolytic degradation of the glucose. During the first five weeks of storage, a slight increase in the level of glucose was observed, and the initial difference between the control and the ionised bulbs remained visible at 10 and 20°C. Meanwhile, at 4°C, the glucose content of the control bulbs was stable; an increase was likewise observed in the glucose level in the irradiated bulbs (Fig. 1a, b and c). After the fifth week, the glucose increased abruptly at the three temperatures reaching 3, 3.5 and 3.7 g$\cdot$100 g^{-1} of fresh weight at 4, 10 and 20°C, respectively. Following this 'peak', the glucose content

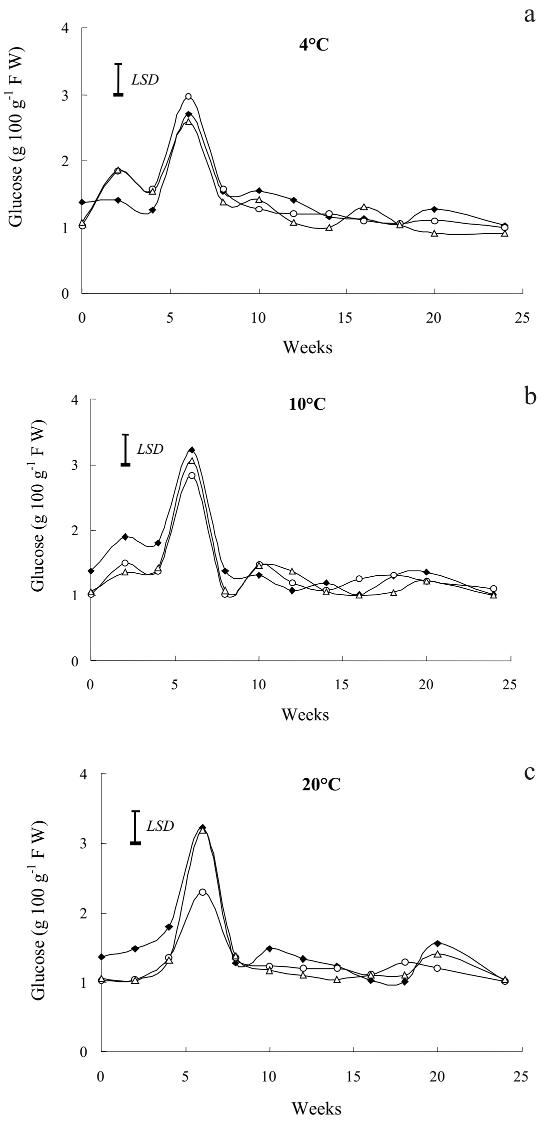


Fig. 1. Effect of irradiation and storage time on glucose content stored at 4 (a), 10 (b) and 20°C (c) (– control; – 0.15 kGy; – 0.30 kGy) (LSD at $\rho < 0.01$).

of both the control and the irradiated bulbs returned to their initial levels. These concentrations remained stable, varying between 1 to 1.5 g · 100 g^{-1} of fresh weight in both the control and the irradiated bulbs during the last 15 weeks storage.

Variations of the fructose content showed similar patterns to that observed with glucose (Fig. 2a, b and c). However, the increase in fructose (not significant) during the first weeks was noted at 4 and 10°C, but at 20°C the fructose variation was identical to the glucose variation. On the other hand, the fructose 'peak' observed between the fifth and tenth week of storage did not exceed 3 g · 100 g^{-1} of fresh weight for either the control or the irradiated bulbs. The same profile was also apparent on the variation of fructose content during the last 15 weeks storage.

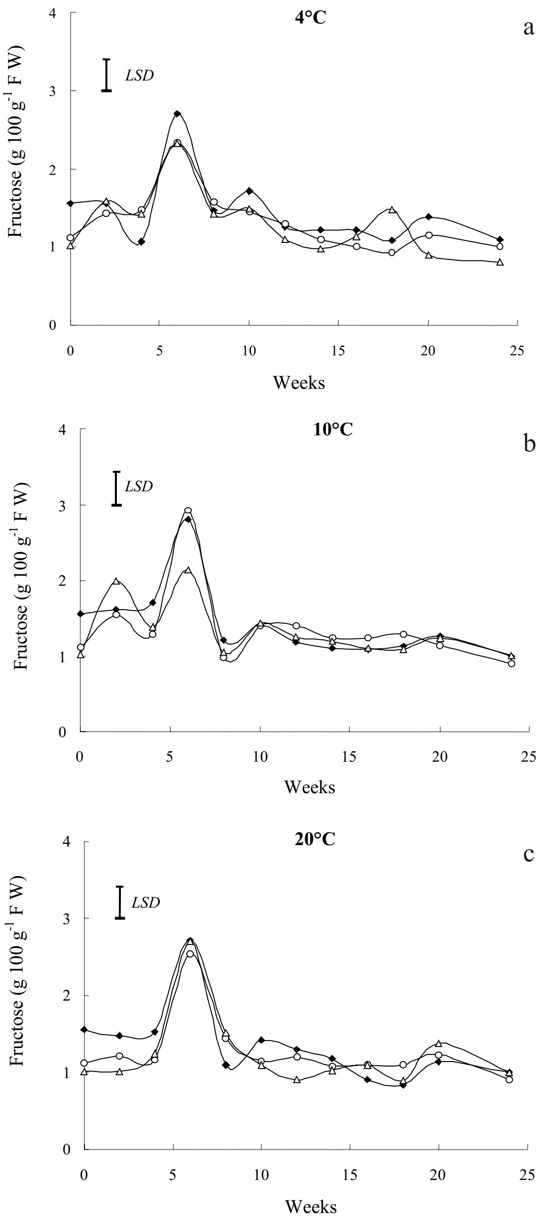


Fig. 2. Effect of irradiation and storage time on fructose content stored at 4 (a), 10 (b) and 20 °C (c) (for keys see Fig. 1).

The fructose/glucose (F/G) ratio of onions stored at different temperatures is presented in Table 1. It was noted in the control onion tissues that the F/G ratio increased with temperature, emphasising the level of glycolytic metabolism which was reduced by the low temperature. However, in the ionised onion tissue, the measured F/G ratios were approximately identical. This could be the result of the low glycolytic catabolism which was disturbed by ionisation damage and emphasised by temperature, and so, cellular activity is directed to the metabolic restoration of damage caused by gamma rays – principally the repair of the genetic material of the cells.

The sucrose content showed a different pattern of variation (Fig. 3a, b and c). Between the fifth and eighth week of storage, a slight peak of sucrose was observed at 10 and 20°C, but did not exceed 1.2 g · 100 g^{-1} of fresh weight. At 4°C, a slightly insignificant decrease in sucrose was observed between the fourth and sixth week of storage. After ten weeks, no significant change was observed among the control and the irradiated bulbs.

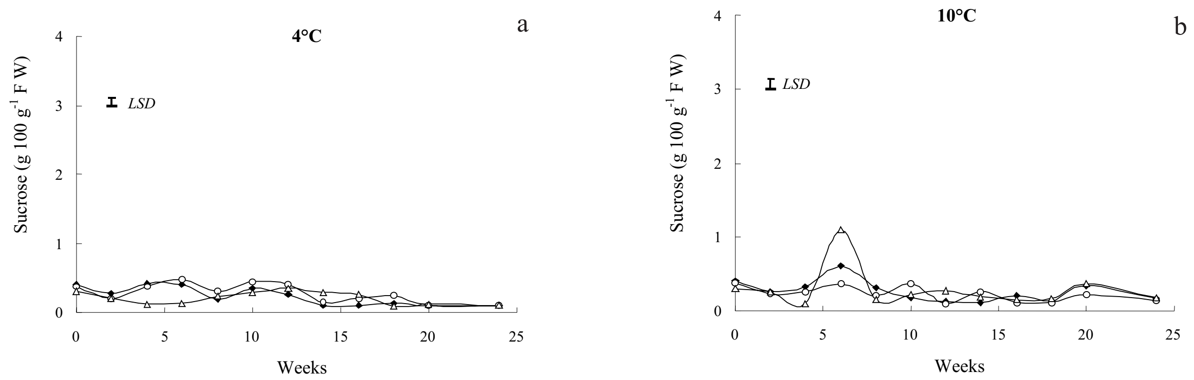
DISCUSSION

Despite the existence of some data on the variation of total soluble sugars or oligosaccharide – irradiated onions [1], little is known about the individual change in sugars during the long storage period of the onion bulb, especially irradiated onions. Croci *et al*. [6] reported a slight increase in the glucose content in both the irradiated (0.05 kGy) and the control bulbs after 3 months of storage at temperatures ranging from 6 to 32°C over 10 months. The levels of disaccharides (including certain oligosaccharides) have also been reported to have increased significantly between the third and fifth months in machine-cooled, outdoorventilated, stored onions [4]. This increase was followed by a subsequent recession after 5 months. Mahmoud *et al*. [10] also reported that the reducing sugar content in the control bulbs increased considerably during the two first months of storage at temperatures ranging from 0 to 4°C, while bulbs irradiated with 0.05 kGy showed less change. The variation of sucrose levels in onions has been less studied. However, the sucrose content of onion bulbs stored at 4°C has been reported to show little change and the level remains constant throughout storage.

There are conflicting reports on the variations of the glucose and fructose in onion bulbs especially during the end of the dormancy period and the beginning of sprouting. This fact is probably due to the difference of the sugar content in different parts of the bulbs where high levels have been observed in the outer layers [13,14]. Temperature is also a major factor affecting sugar change in onion bulbs [7,14].

T a b l e 1. Effect of temperature and irradiation dose on fructose/glucose ratio of onion bulbs during storage

Weeks	Control			0.15 kGy			0.30 kGy		
	4°C	10°C	20°C	4°C	10°C	20°C	4°C	10°C	20°C
0	1.14	1.14	1.14	1.10	1.10	1.10	0.96	0.96	0.96
2	1.11	0.85	0.99	0.78	1.03	1.16	0.85	1.46	0.99
4	0.85	0.94	0.85	0.94	0.94	0.86	0.93	0.97	0.94
6	1.00	0.87	0.84	0.79	1.03	1.10	0.90	0.70	0.84
8	0.95	0.88	0.86	1.00	0.97	1.07	1.04	0.97	1.09
10	1.10	1.07	0.96	1.14	0.94	0.93	1.05	0.98	0.94
12	0.90	1.10	0.97	1.08	1.17	1.00	1.04	0.91	0.82
14	1.05	0.92	0.95	0.92	1.15	0.90	0.98	1.13	0.99
16	1.08	1.08	0.87	0.91	0.99	0.98	0.88	1.10	1.00
18	1.05	0.87	0.83	0.89	0.98	0.84	1.44	1.04	0.81
20	1.09	0.93	0.72	1.05	0.93	1.03	1.00	1.02	0.97
24	1.08	0.98	0.98	1.00	0.82	0.89	0.89	1.01	0.96
Mean	1.03	0.97	0.91	0.97	1.00	0.99	1.00	1.02	0.94
SD	0.09	0.10	0.11	0.12	0.10	0.11	0.15	0.17	0.08



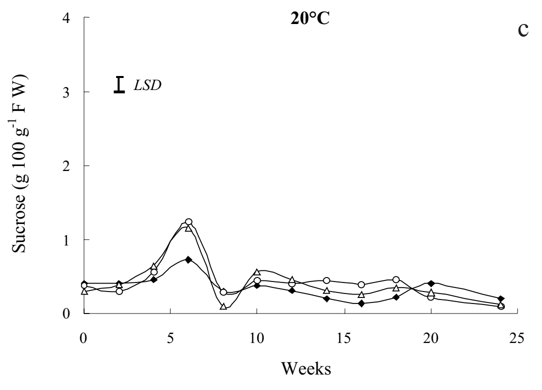


Fig. 3. Effect of irradiation and storage time on sucrose content stored at 4 (a), 10 (b) and 20 °C (c) . Explanation as on Fig. 1).

CONCLUSION

In conclusion, it appears that irradiation does not affect the sugar content of onion bulbs during storage. This is linked more to the dormancy stage and is influenced by temperature changes. On the other hand, sugars could be a good indicator of the freshness of the onion bulb; a decrease could mean a loss of quality. This suggestion is based on the loss of firmness and shrivelling observed after three months or more of storage particularly at temperatures above 15°C. However, further investigation is required to study the variation of sugars in the different layers of the onion bulb especially in the outer layers which are considered to be the main site for the accumulation and storage of carbohydrates and the inner 'bud' which is the site of metabolic activity.

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