

Sensory properties of iodine-biofortified potatoes

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Abstract

The present study assessed the sensory impact of potatoes biofortification with iodine and the stability of iodine during six months of storage. Four biofortified cultivars (*Cupido*, *Marabel*, *Orchestra* and *Universa*) and their controls (non-biofortified) were evaluated. Descriptive analysis was applied with a panel to describe the sensory properties, and triangle tests were applied with consumers to evaluate perceivable differences between controls and respective biofortified samples at the end of shelf life. Iodine content was quantified on raw potatoes for three periods of storage. Descriptive analysis showed some differences between controls and iodine-biofortified samples, especially in texture (hardness). However, consumers did not significantly discriminate fortified from unfortified samples. Iodine was stable during storage in all varieties. *Orchestra* cultivar showed the highest iodine content, while *Universa* the lowest.

Keywords: biofortification, descriptive analysis, essential micronutrient, functional food, potato, triangle test

Introduction

Iodine is an essential micronutrient consumed with diet, and is necessary for the biosynthesis of thyroid hormones which regulate metabolic functions (Trumpff *et al.*, 2013). The daily recommended iodine intake ranges from 90 to 250 µg, depending on several factors, among others, age and physiological status (e.g. childhood, adulthood, pregnancy/lactation) (Zimmermann *et al.*, 2012). Inadequate iodine intake is currently one of the main micronutrient deficiencies worldwide, leading to a spectrum of clinical and social issues called ‘Iodine deficiency disorders’ (Gonzali *et al.*, 2017) and iodine deficiencies still represent a severe problem in certain geographic areas (Khattak *et al.*, 2017). Iodine biofortification in vegetables is a promising strategy to increase iodine intake and overcome iodine deficiencies in human diet. However, the main critical issues in biofortification of iodine vegetables rely on the stability of the mineral during storage

and the potential sensory modifications, which can compromise acceptability of fortified food.

There are different strategies to address increase in iodine such as mineral supplementation, food fortification and biofortification of crops (Comandini *et al.*, 2013). Biofortification is applied to increase the bioavailable nutrient content of the edible portion of crop plants (Hotz, 2013). Biofortification of plant foods can be obtained by the following three ways: agronomic biofortification, conventional plant breeding of selected cultivars, and genetic engineering (Carvalho and Vasconcelos, 2013). The aim of the agronomical approach is to increase micronutrients through mineral fertilisers and/or through the improvement of soil mineral elements’ mobilisation (Saltzman *et al.*, 2013). Recently, many authors have developed and tested specific agronomical practices to increase iodine content in different vegetables and crops, such as potato and tomato (Caffagni *et al.*, 2011; Zanirato

and Mayerle, 2009); barley and wheat (Caffagni et al., 2011); spinach and lettuce (Smoleń et al., 2014; Weng et al., 2013); cabbage, coriander, cucumber, eggplant, long cowpea and hot pepper (Weng et al., 2013); carrot and onion (Zanirato and Mayerle, 2009).

As a general rule, food fortification should not alter the stability, colour or flavour of the vehicle food (Dwyer et al., 2015). Iodine salts may theoretically be involved in colour or oxidative reactions, since iodide is a strong reducing agent and iodate is a strong oxidizing agent (Winger et al., 2008). Since the modification of the sensory properties of food can negatively affect consumers' hedonic responses, it is necessary to maintain an adequate level of acceptance when dealing with fortified foods. In fact, in spite of certain consumers that compromise on taste when consuming healthy foods (Verbeke, 2006), often functional foods are characterised by critical sensory properties which are more disliked by consumers compared to conventional foods (Dal Bello et al., 2017; Torri et al., 2016).

The effect of iodine on food sensory quality has been studied by many authors (Greis et al., 2018; West and Koning, 1995). On biofortified vegetables, particularly considering potatoes, studies were performed regarding the process of biofortification (Caffagni et al., 2011; Zanirato and Mayerle, 2009), the stability of iodine during cooking (Caffagni et al., 2012; Comandini et al., 2013) and the bioavailability of iodine (Tonacchera et al., 2013).

However, to the present authors' best knowledge, no study has explored the stability of iodine during storage in biofortified potatoes and its effect on sensorial properties.

Therefore, the aim of the present study was two-fold: (1) to evaluate the effects of iodine biofortification on sensory properties by describing the sensory properties of controls and biofortified samples (descriptive analysis [DA]) and by verifying whether biofortified cultivars were discriminated from non-fortified controls (triangle test); and (2) to evaluate the chemical stability of iodine in raw biofortified potatoes during storage (iodine analysis). Since prior results showed that iodine is stable during domestic cooking, including baking (Comandini et al., 2013), the analysis of iodine was done directly on raw potatoes to establish the following: (1) the starting natural quantity of iodine in each cultivar; (2) the effect of iodine biofortification on each cultivar immediately after harvesting (storage time at which potatoes are extremely fresh) and (3) stability at the end of six months (storage time corresponding to end of shelf life, the moment at which the potatoes are the least fresh). Sensory analyses were conducted at the end of shelf life (i.e. six months),

which was potentially the most critical moment, since the product was not fresh.

Materials and Methods

Growing and processing of potato cultivars

Potatoes (*Solanum tuberosum*) are grown in a limited zone of Emilia-Romagna region in Italy, and these were kindly donated by Pizzoli S.p.A. (Budrio, Italy). Four international cultivars were chosen for the biofortification process: *Cupido*, *Marabel*, *Orchestra* and *Universa*. These cultivars were chosen because of their maximum usage to produce fresh potatoes for global commercial level. For each cultivar, control and biofortified samples were obtained from the same field of growth to minimise any variability factor other than biofortification process. One batch was analysed for each cultivar. In text, letter 'C' is used to identify controls, while letter 'B' is used for biofortified samples. In all, eight samples were evaluated (*Cupido_C*, *Marabel_C*, *Orchestra_C*, *Universa_C*, *Cupido_B*, *Marabel_B*, *Orchestra_B* and *Universa_B*). Iodized potatoes were obtained by means of a patented agronomic procedure (Zanirato and Mayerle, 2009) through foliar fertilisation realised during the growing season. The harvest was done three weeks after the iodine treatment. Potatoes were stored under conventional industrial storage conditions: in a plastic box put in a warehouse designed for potato storage in absence of light, and in ventilated and conditioned atmosphere at 8°C and 80% of relative humidity during all storage period. No sprout inhibitors were used during storage. A period of six months was chosen as a shelf life, since it is a reasonable/representative storage time for commercial potatoes in controlled conditions before they are packaged and distributed immediately.

Sensory evaluation

All sensory tests were performed after six months of storage. Participants freely joined the sensory activities and written informed consent was obtained from all participants before inclusion in the tests. The study was in conformity with the Declaration of Helsinki. Prior to sensory evaluations, assessors received both verbal and written instructions regarding the evaluation procedures.

Preparation of samples

Whole unpeeled potatoes were washed in tap water and cooked for 80 min in a steam oven (Chef top, Unox S.p.A., Padova) at 100°C and 100% of relative humidity. After cooking, whole potatoes were cooled at a room temperature of 20°C for 2 h. Approximately 30 min prior to sensory evaluations, potatoes were cut in cubes with side

of 15 mm and put on white plastic plates codified with a random three-digit code. Each container was closed with a plastic lid. Water was provided as palate cleanser at the start and between successive samples. The same preparation procedure was used in both sensory tests.

Descriptive analysis

Sensory profiles of eight potato samples were determined by the sensory panel of ASTRA laboratory (Imola, Italy). Test room was designed and managed following the ISO 8589:2007 (ISO 2007). The panel comprised eight trained judges (60% females, aged 27–45 years). The sensory panel was selected, trained and continuously monitored following the ISO 8586-1:2012 (ISO 2012). The panel evaluated the eight potato samples with an internally adapted procedure to establish a sensory profile developed following the ISO 13299:2016 (ISO 2016). The sensory profile approach is referred to in the text as descriptive analysis. A list of six attributes (two for tastes, one for flavour, and three for texture) was finally selected by the panel. Attributes, each of which was defined by a specific definition, were evaluated on nine-point scale (Table 1). For the purpose of tasting attribute, assessors were required to taste the sample, swallow and evaluate attributes for taste and flavour. Then, panellists were required to cut the sample with a knife to re-taste it and to evaluate texture properties. Samples were presented to panellists monadically and served in single-use, white plastic containers codified with a random three-digit code. A 1-min break was enforced between samples, when panellists rinsed their mouth with water. The descriptive analysis was conducted in two replicates. Each descriptive evaluation session lasted for approximately 1.5 h.

Triangle tests

The triangle test approach was chosen to find any difference between samples without specifying the sensory

characteristic(s) that differ. Triangle tests were performed following ISO 4120:2004 (ISO 2004). Four triangle tests were performed in total (12 samples). The evaluation session included two subsets, each comprising two triads. Each triad had three codified samples, two of which were identical, and one was the odd sample. Assessors must identify the odd sample. Within each triad, the comparison was between the biofortified sample and the correspondent control. Samples were served according to a randomised design (ABB, BAA, AAB, BBA, ABA and BAB). A group of 46 subjects were involved (68% females, aged 24–50 years). Instructions required the assessors to taste the samples according to the provided order (from left to right), and to select the sample that they perceived as different from the other two within each triad. Assessors were asked to provide an answer even if they were not sure. Re-tasting was permitted. No time limitation was imposed on assessors. The presentation order of the triads was randomized across subjects. All evaluations were conducted between 12:00 noon and 2:00 pm.

Chemical analysis

Reagents

High purity grade solvents were used for iodine extraction. Tetramethylammonium hydroxide solution (TMAH, 1 M) was bought from Sigma Aldrich (St. Louis, MO), and hydrogen peroxide solution (H₂O₂ 30% m/m) was from Carlo Erba (Arese, MI, Italy). Ion exchange water (18 M Ω) was obtained from Millipore Direct Q5 system (Millipore Co., Bedford, MA).

Iodine analysis

Iodine analysis was performed on controls and treated potatoes at three different periods: immediately after harvest (T0), after three months (T3) and after six months of

Table 1. Sensory attributes and definitions used by the trained panel in descriptive analysis to describe iodine-biofortified potatoes and controls.

Sensory modality	attribute	Definition	Scale
Taste	Sweet	The perception of sweet taste on the tongue	1 = very low; 5 = moderate; 9 = very intense
	Salty	The perception of salty taste on the tongue	1 = very low; 5 = moderate; 9 = very intense
Flavour	Typical potato flavour	The presence of an overall flavour typical for cooked potato perceived after swallowing	1 = very low; 5 = moderate; 9 = very intense
Texture	Hardness	The resistance of flesh to knife cutting and mastication (to the force impressed by teeth at the first bite)	1 = soft; 5 = neither soft nor hard; 9 = hard
	Moistness	The presence of liquid in the cut surface and perception of suiciness in the mouth during mastication	1 = dry; 5 = neither dry nor wet; 9 = wet
	Granulation	The presence of granules with a certain dimension, perceived during mastication	1 = coarse; 5 = neither coarse nor fine; 9 = fine

storage (T6). T3 and T6 were measured only for a group of biofortified samples. A representative quantity of fresh potatoes was homogenised. About 0.5 g of sample was weighed directly in pyrex test tubes. Iodine was extracted by adding 6 mL of TMAH solution (0.25 M) and 2 mL of H₂O₂ (30%) followed by microwave mineralisation (Mars Express 5, CEM srl, Cologno al Serio, Italy). The extract was diluted with ultrapure water, centrifuged and filtered following the procedure previously developed (Comandini *et al.*, 2013). Iodine content was determined with an inductively coupled plasma mass spectrometer (ICP-MS) (Agilent, Palo Alto, CA) using the following parameters: RF power 1550 W, and argon flow rates of 1.05 L/min and 0.2 L/min, respectively, for carrier gas and make-up gas. Instrument calibration was performed by employing iodine standards of up to a concentration of 100 mg/L in diluted TMAH solutions. Iodine analysis was done in triplicate.

Statistical analysis

The effect of samples on the perceived intensity of descriptors from panel was estimated using two-way mixed Analysis of Variance (ANOVA) models (random factor: judge; fixed factor: sample; model without interactions) separately conducted on each variable (sensory descriptor) considering eight products. All ANOVA models were followed by Tukey HSD test ($P < 0.05$). A Principal Component Analysis (PCA) was conducted on the mean intensity ratings of significant attributes obtained from a two-way mixed ANOVA, with the option of bootstrap hulls, which permitted to visualise the confidence areas of each sample. *T*-tests ($p < 0.05$) were used to estimate Differences between the mean values obtained by the panel for both control samples and means obtained by the relative biofortified samples. For the triangle test, the following parameters were defined for 46 assessors: an α -risk of 0.10, a β -risk of 0.30 and a p_d of 0.20. The mean value of the three replicates was used for iodine analysis. Values of iodine are expressed in the text as mean and standard error of the mean for each storage time. A one-way ANOVA was conducted to estimate the effect of cultivar on the initial iodine content after harvesting among control samples (fixed factor: cultivar). The effect of iodine treatment within each cultivar was estimated after harvesting by four *t*-tests ($P < 0.05$), each comparing the content of iodine in the biofortified sample versus the related control sample. To assess the combined effect of the cultivar and the storage time on the final iodine content, a two-way fixed ANOVA was conducted (fixed factors: cultivar, and time of storage; model with interactions) considering 12 samples (four biofortified cultivars \times three storage periods). Analyses were conducted with XLStat 2019.1.1 (Addinsoft, Boston, USA; package sensory).

Results and Discussion

Sensory properties

Sensory profiles

The sensory effects of addition of iodine to food have been described in previous papers (Greis *et al.*, 2018; West and Koning, 1995). However, to the best of present authors' knowledge, this is the first study reporting on the systematic description (done with a trained panel) of the sensory profiles obtained from biofortified potatoes baked in an oven.

The two-way mixed ANOVA models indicated a significant effect of the sample ($P < 0.05$) for all attributes except for salty ($F = 2.04$, $P = 0.06$). Mean intensity values obtained from replicates of significant attributes were submitted for PCA. Two principal components were extracted, which accounted for 82.5% of the total data variance, with PC 1 accounting for 58.1% and PC 2 for 24.4% variance (Figure 1A).

The first component (PC 1) was positively associated with two textural attributes: moistness and granularity, and sweetness, and negatively associated with the typical potato flavour. Granulation, moistness and sweetness were highly correlated to each other. The second component (PC 2) was positively associated with hardness, and negatively associated with granularity. The two *Universa* samples (*Universa_B* and *Universa_C*) were highly and positively associated with PC 1, thereby showing a positive correlation with attributes having a positive loading on this component. Instead, *Marabel* (*Marabel_B* and *Marabel_C*), *Cupido* (*Cupido_C* and *Cupido_B*) and *Orchestra_B* samples had a negative correlation on PC 1, thereby associated with a high intensity of typical potato flavour. However, *Cupido_B*, *Cupido_C*, *Marabel_C*, *Orchestra_C* and *Universa_C* had a negative score on PC 2. The bootstrap hulls plot showed samples with their confidence areas (Figure 1B). Some overlapping was observed in terms of perceptive properties, especially between *Marabel_C* and *Cupido_B* and between *Cupido_C* and *Marabel_B*, suggesting perceptive similarities between these two cultivars. Instead, *Universa_B* was clearly the most diverse sample which did not show perceptive overlaps with other samples.

The sensory profiles of the four cultivars comparing the control samples with the related biofortified samples at T6 are shown in Figure 2. Observed modifications in the sensory properties may have been induced by the iodine treatment in field, which was done in the last period of growth of tubers (about 2 weeks before harvest). In general, a few differences were found between controls and biofortified samples, and the sensory modifications observed from the *t*-test were small, similar to a recent

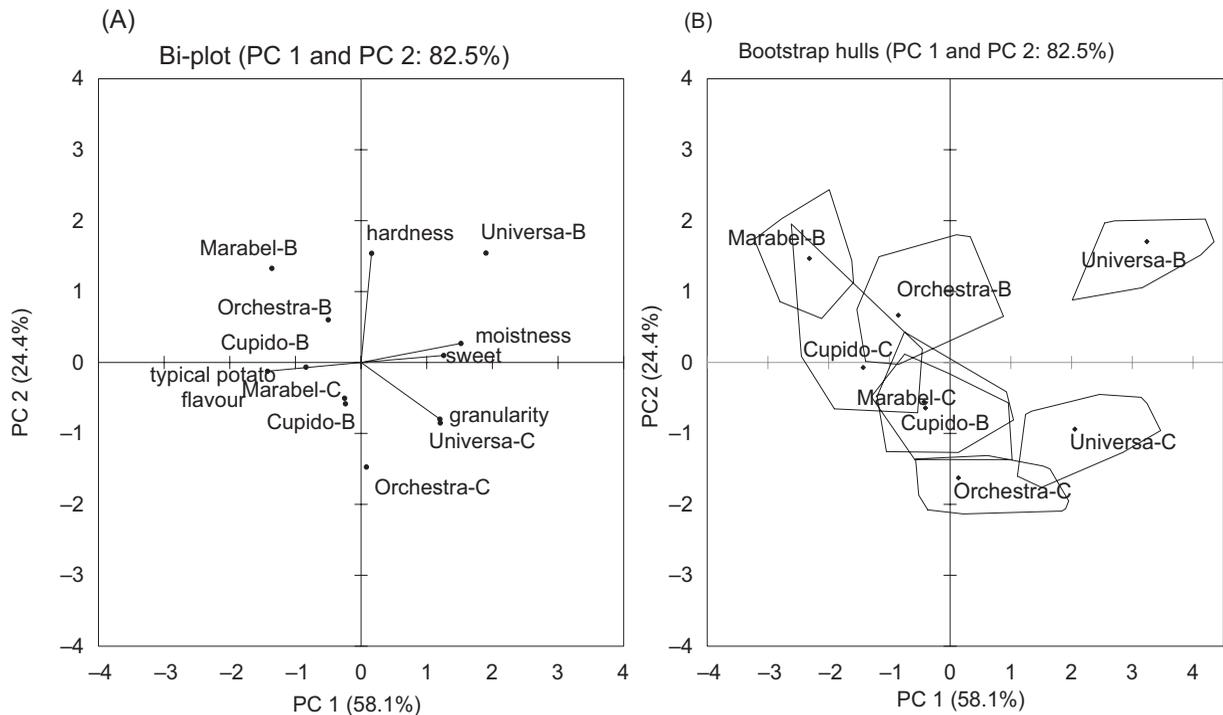


Figure 1. Bi-plot (1A) and bootstrap hulls plot (1B) from principal component analysis (PCA) of significant attributes used in descriptive analysis to describe eight samples of potatoes, including four controls (*Cupido_C*; *Marabel_C*; *Orchestra_C*; and *Universa_C*) and four biofortified samples (*Cupido_B*; *Marabel_B*; *Orchestra_B*; and *Universa_B*).

study which assessed the sensory modifications induced by addition of iodine in wheat bread, sausages and pickled cucumbers (Greis *et al.*, 2018).

Cupido was the only cultivar that did not show any significant differences in the comparison of profiles (Figure 2A).

The typical potato flavour and sweetness were not affected by the treatment of iodine in any variety. The intensity of descriptor 'typical potato flavour' was in agreement with a previous study, showing that the addition of salt containing 400-mg iodine from potassium iodide or iodate did not affect the flavour of boiled potatoes and boiled rice (West and Koning, 1995). Moreover, iodine content of up to 100 mg/kg did not affect the sensory attributes of pickle (Greis *et al.*, 2018).

On the contrary, in the current study, the biofortification seems to influence the texture, with a general increase in the perceived hardness, which significantly increased in three out of four biofortified samples (*Marabel*, *Orchestra* and *Universa*).

The two other textural attributes (moistness and granularity) varied depending on the cultivar.

In *Marabel*, the biofortified sample (*Marabel_B*) showed a significant decrease ($P = 0.03$) in granularity and a significant increase in hardness ($P = 0.02$) (Figure 2B).

In biofortified *Orchestra*, the hardness significantly increased ($P \leq 0.01$), while the perceived saltiness decreased ($P = 0.03$) (Figure 2C). In biofortified *Universa* (Figure 2D), both hardness ($P \leq 0.001$) and moistness ($P \leq 0.01$) increased significantly.

In general, the texture of potatoes is determined by several mutually dependent factors (Jarén *et al.*, 2016). The consistent increase in hardness found in the current study in biofortified samples may have been linked to the modification induced by the iodine within the starch structure. In fact, it is known that iodine may be bounded within the helical V-amylose component (Yu *et al.*, 1996), and this modification in the structure can translate into a microscopical increase in the perception of hardness. A few existing studies on the effect of iodine on texture seems inconsistent across different food products. Greis and colleagues (2018) found the largest deviation from the reference for tenderness for sausages but no difference in hardness for iodized and non-iodized pickles. Meat samples (sausages) containing a high quantity of iodine were tenderer (Greis *et al.*, 2018), probably because of the variation in their water-holding capacity (WHC). Iodate appeared to soften vegetable pickles in brine during storage (12 days) (Amr and Jabay, 2004), which goes opposite to our results. Taken together, these results suggest that a few sensory modifications induced by the iodine biofortification strongly depend on the type of food matrix used.

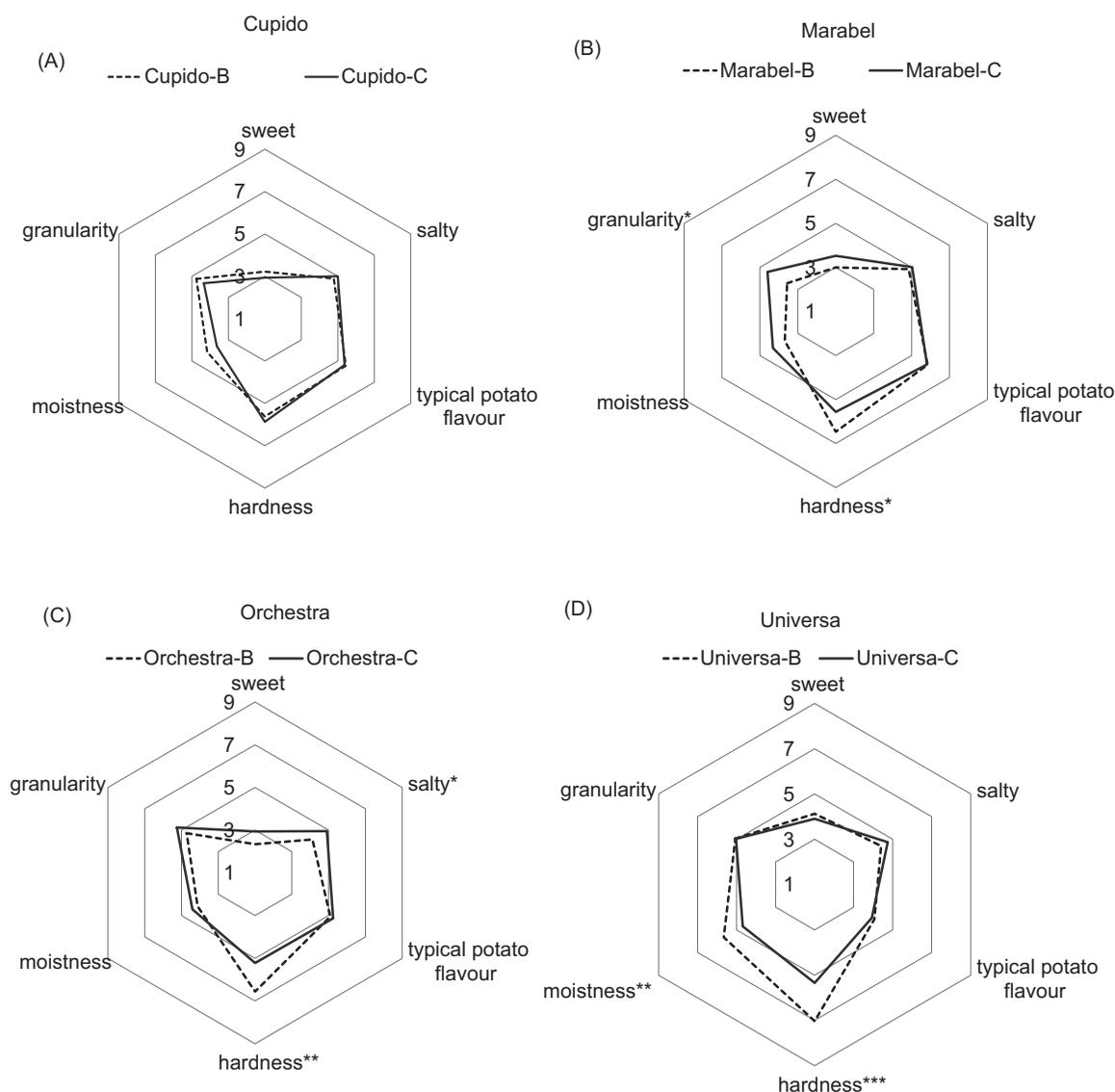


Figure 2. Sensory profiles of the control samples (continuous lines) and biofortified samples (dashed lines) for the cultivars: (A) *Cupido*, (B) *Marabel*, (C) *Orchestra* and (D) *Universa*. Asterisks indicate significant different mean values from *t*-tests for the considered attribute (* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$).

Overall sensory difference

Results of triangle tests for the four cultivars are shown in Table 2.

No significantly perceivable differences were found between any control sample and its respective biofortified sample at T6, thus indicating that the biofortification was not perceived in the population of subjects. The fact that no significant differences were found from triangle tests between treated samples and control samples suggested that differences found from descriptive analysis were minor, and therefore it was unlike that naive consumers may have noticed them. The two sensory techniques gave some slightly different outputs because descriptive analysis was conducted by trained assessors,

while triangle tests with naive consumers. Apart from the different expertise of the two groups, the approach was fully different. Triangle test is an overall difference test (Meilgaard *et al.*, 2007b), while descriptive analysis is an approach that requires an analytical evaluation of each descriptor (Meilgaard *et al.*, 2007a).

Iodine content and stability

Table 3 shows the iodine content after harvest (T0) in controls, and that in biofortified cultivars at three storage periods (T0, T3 and T6). The amount of iodine present in control samples (not treated) was derived from the environment elements (soil, water and air)

Table 2. Results of triangle tests conducted at T6 to estimate significant differences between biofortified samples and their respective controls. Each row shows the results of each cultivar from comparison between the biofortified samples and the relative control samples.

Cultivar	Assessors (N)	Critical number of correct responses	Correct responses given (n)	p_d	P-value
<i>Cupido</i>	44	20	18	0.11	0.18
<i>Marabel</i>	44	20	19	0.15	0.11
<i>Orchestra</i>	47	21	20	0.14	0.12
<i>Universa</i>	46	20	17	0.05	0.35

Note: p_d is the maximum proportion of assessors being able to detect a difference between products.

Table 3. Iodine content ($\mu\text{g}/100\text{ g}$) in controls ('C') and relative iodine-biofortified samples ('B') at three different periods of storage (after harvesting = T0, after three months = T3 and after six months of storage = T6).

Cultivar	Samples	Storage time		
		T0*	T3	T6
<i>Cupido</i>	<i>Cupido_C</i>	2.2 ± 0.3		
	<i>Cupido_B</i>	40.1 ± 3.9 ^{a,b,c,d*}	36.4 ± 3.9 ^{a,b,c,d}	37.0 ± 3.9 ^{a,b,c,d}
<i>Marabel</i>	<i>Marabel_C</i>	3.2 ± 0.3		
	<i>Marabel_B</i>	32.1 ± 3.9 ^{b,c,d,e*}	24.5 ± 3.9 ^{c,d,e}	22.9 ± 3.9 ^{c,d,e}
<i>Orchestra</i>	<i>Orchestra_C</i>	6.7 ± 0.3		
	<i>Orchestra_B</i>	52.4 ± 3.9 ^{a*}	42.4 ± 3.9 ^{a,b,c}	48.7 ± 3.9 ^{a,b}
<i>Universa</i>	<i>Universa_C</i>	2.8 ± 0.3		
	<i>Universa_B</i>	23.7 ± 3.9 ^{c,d,e*}	20.9 ± 3.9 ^{d,e}	15.7 ± 3.9 ^e

Values are mean ± standard error of three measurements.

*Mean values of biofortified samples significantly differ from mean values of respective control samples at T0 from *t*-test ($P \leq 0.01$).

Different letters in mean values across the 12 biofortified samples indicate significantly different iodine contents from two-way ANOVA followed by Tukey's HSD test ($P < 0.05$).

(Osterc *et al.*, 2011). At T0, *Orchestra_C* had the significantly highest iodine content ($6.7 \pm 0.3 \mu\text{g}/100\text{ g}$) compared to the other control samples, suggesting that this cultivar is naturally richer in iodine.

In general, standard errors associated with the iodine analysis were high. This was because the sample preparative phase of this method (extraction) suffers from an intrinsic variability of sub-samples (replicates) that can greatly vary despite a proper homogenisation of the matrix (e.g. for the water content of single tuber, for different accumulations of micro- and macro-components in tuber etc.), thus resulting in high variations in standard errors.

As expected, *t*-test confirmed that the iodine content significantly ($P \leq 0.01$) and strongly increased in all biofortified samples, independent of the initial iodine content (Table 3). This suggests that the agronomic treatment was effective in fresh potatoes, confirming results of other authors (Caffagni *et al.*, 2011, 2012; Zanirato and Mayerle, 2009).

The four cultivars showed different accumulation efficiencies in agreement with a previous study, which observed that the accumulation efficiency varied not only across potatoes (Caffagni *et al.*, 2012) but also for different amounts of iodine provided (Caffagni *et al.*, 2011). The increased ratio (the ratio of amount of iodine in biofortified and control samples) was approximately 18 (for *Cupido*), 10 (for *Marabel*) and 8 times more (for *Orchestra* and *Universa*). Therefore, *Cupido* showed the highest increased ratio. These differences in accumulation efficiency across varieties could be derived from different responses of cultivars to iodine treatment. Since the iodine behaviour in a soil–plant system is very complex due to the high number of factors involved (Fuge and Johnson, 2015), different varieties of plants absorb iodine differently.

The two-way ANOVA showed a significant strong effect of the biofortified cultivar ($F = 23.352$, $P < 0.001$) on the final iodine content but no effect of the storage time ($F = 3.088$, $P = 0.064$) nor of the interaction of cultivar and storage time (cultivar × storage time; $F = 0.471$, $P = 0.823$) (data not shown). The lack of effect of storage

time indicated that the content of iodine is substantially stable during the considered time, in agreement with a previous study (Caffagni *et al.*, 2012), which noted no significant effect of storage time on iodine content in potato tubers. The lack of effect of interaction (cultivar × storage time) indicated similar trends in iodine contents over time across the considered cultivars.

Instead, the strong effect of cultivar indicated a difference in the total iodine amount across the biofortified cultivars, as shown in Table 3. After six months of storage, among the biofortified samples, *Orchestra_B* had significantly the highest amount of iodine ($48.7 \pm 3.9 \mu\text{g}/100 \text{ g}$), not significantly different from *Cupido_B* ($37.0 \pm 3.9 \mu\text{g}/100 \text{ g}$), followed by *Marabel_B* ($22.9 \pm 3.9 \mu\text{g}/100 \text{ g}$) and *Universa_B* ($15.7 \pm 3.9 \mu\text{g}/100 \text{ g}$), which did not differ significantly from each other. *Orchestra* cultivar seemed to be the most suited variety for iodine biofortification, while *Universa* cultivar is the least suited because of its lowest accumulation efficiency (according to the iodine increased ratio after treatment) and the lowest final content of iodine after six months.

Conclusions

On the one hand, the data obtained from the present work confirmed the effectiveness of the agronomical practice of iodine biofortification in potatoes. Iodine content was stable for six months under the conventional storage conditions in all cultivars. On the other hand, this study extended the knowledge by providing a systematic description of the sensory effects of iodine-biofortified potatoes, considering four different potato cultivars (*Cupido*, *Marabel*, *Orchestra* and *Universa*).

The descriptive analysis highlighted a few differences between biofortified and control samples, mainly in texture (hardness), probably because of modifications in the starch structure of potatoes induced by iodine. However, differences were small and were not detected by consumers in triangle tests. Therefore, iodine biofortification seems to be a suitable and promising technique for potatoes, since it does not compromise the sensory properties and it allows to develop functional vegetables (that is products with improved nutritional characteristics), which could be successful by consumers. A further development of the study could be the exploration of consumers' perception related to liking of biofortified samples, targeting specific consumers (e.g. consumers with specific nutritional needs).

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Author Contributions

All authors contributed to the study's conception and design. M. Piochi undertook the analyses and wrote the paper. All authors critically contributed and commented on the previous versions of the manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards

The research was conducted on human volunteers, and it was in conformity with the Declaration of Helsinki. Written informed consent was obtained from all participants before inclusion in the sensory tests.

Conflict of Interest

The authors declare that they have no conflict of interest. Vegetables were supplied free of charge with no obligation between researchers and suppliers.

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