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ORIGINAL ARTICLE

Phytochemical Screening, Nutritional Properties and Biological Activities of Sweet and Conventional Potato Planted in Morocco

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Abstract

This study aimed at studying phytochemical composition, nutritional properties and biological activities (antioxidant and anti-inflammatory) of two potato varieties (sweet potato (SP): *Ipomoea batatas* L. and conventional potato (CP): *Solanum tuberosum* L.) planted and consumed in Morocco. For this, potato samples (SP and CP) were firstly subjected to phytochemical and nutritional analysis, including water content, total and reducing sugars, proteins, lipids, vitamin C, carotenoids, phenolic compounds and flavonoids. Secondly, phenolic compounds extracts were subjected to biological activities namely antioxidant and *invitro* anti-inflammatory. Potato extracts antioxidant activity was tested by DPPH and total antioxidant capacity (TAC) methods. Proteins and lipids contents were found much higher in SP (5.21 ± 0.26 and 0.29 ± 0.02 g/100g DW) respectively than in CP (2.93 ± 0.15 and 0.11 ± 0.01 g/100g DW) respectively. Besides, total and reducing sugars contents were 16.65 and 2.53 g/100g DW in the CP, and 12.47 and 2.13 g/100g DW in the SP, respectively. The antioxidant activity of different SP extracts was found to be higher than those of CP, by using DPPH and TAC methods. These findings could be explained by SP richness in carotenoids (212 ± 10.60 mg/100g DW), phenolic compounds (130.11 ± 6.51 mg GAE/100g DW), flavonoids (85.03 ± 4.2 5mg QE/100g DW) and vitamin C (471.33 ± 23.57 mg/100g DW). Exclusion chromatography done by Sephadex G50 showed that polymeric phenolic compounds in SP were more abundant when compared to monomeric ones. This difference was consistent with the anti-inflammatory activity assessed in vitro.

Keywords Potato · *Ipomoea batatas* L. · *Solanum tuberosum* L. · Phytochemicals · Nutritional value · Bioactive compounds · Antioxidant · Anti-inflammatory

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Abbreviations

Abs	Absorbance
AAE	Ascorbic acid-equivalent
BSA	Bovine serum albumin
CA	Caffeic acid
CQA	Caffeoylquinic acid
Cat	Carotenoids
C	Concentration
CP	Conventional potato variety (*Solanum tuberosum* L.)
DNS	3,5-Dinitrosalicylic acid
DPPH	2,2-Diphenyl-1-picrylhydrazyl
DHA	Docosahexaenoic acid
DW	Dry weight
EPA	Eicosapentaenoic acid
F/PC	Flavonoid and phenolic compound ratio
FD	Fortification degree
FW	Fresh weight
GA	Gallic acid
GAE	Gallic acid-equivalent
IC50	Half-maximal inhibitory concentration
IPD	Inhibition of protein denaturation
ε_λ	Molar extinction coefficient
NRS	Non-reducing sugars
OD	Optical density
OS	Oxidative stress
PC	Phenolic compounds
Prt	Protein
QE	Quercetin-equivalent
RS	Reducing sugars
STDV	Standard deviation
SP	Sweet potato variety (*Ipomoea batatas* L.)
SPPs	Sweet potato proteins
TAC	Total antioxidant capacity
TCC	Total carotenoids content
TS	Total sugars
USA	United States of America
WC	Water content

1 Introduction

Oxidative stress (OS) and inflammation are correlated and their interaction contributes to many world's leading diseases, including neurodegenerative disorders [1], diabetes (types 1 and 2) and cardiovascular diseases [2]. The OS induced by poor dietary habits can be corrected by a good diet that ensures the attenuation of free radicals by the body's own antioxidant mechanisms. This has been demonstrated through various molecular damage biomarkers, etc. [3]. Since free radicals have undesirable effects on public's health, consumers are becoming increasingly concerned about their diet, and consequently adhering to good healthy consumption habits, including bioactive antioxidant compounds consumption [4]. Prolonged inflammation can lead to the development of cancer [5]. The study of this phenomenon remains crucial, as every body's cell is potential site of a struggle between pro-oxidants that induce inflammation and antioxidants (nutritional and metabolic) that suppress it [6].

Worldwide dietary recommendations consist of fruit and vegetable consumption to prevent various diseases. In addition to macro- and micronutrients, these foods contain some phytochemicals known with their strong antioxidant activity [7]. Regular intake of fruits and vegetables has beneficial effects on human health, reducing the incidence of chronic disorders such as cardiovascular diseases and certain cancers [8]. It has been reported that a synergistic effect exists between natural compounds such as carotenoids, flavonoids and other bioactive molecules, with high antioxidant activity, to prevent body's cellular structures damage [9].

The food situation in different parts of the world is leading to a transition from the mass consumption of conventional potato (CP) to the adoption of the highly nutritious sweet potato (SP), which adapts easily to different soil types and, in addition, helps to protect them against erosion [10]. Indeed, previous studies on the benefits of SP have shown that this vegetable is considered highly nutritious and has human health benefits as an antioxidant, anti-inflammatory, anticancer, antidiabetic, antimicrobial, cardioprotective, anti-obesity, antiulcer and corrector of vitamin A deficiency [11, 12]. Waseem et al. [13] demonstrated the ability of SP to play a nutraceutical role due to its health benefits; and considerable progress has been made in diversifying the use of SP for alternative foods such as yogurt and juices [14], innovative applications such as ice cream, and non-carbonated drinks [15]. On the other hand, previous studies have highlighted the possibility of converting SP into high-added value products [16]. The development of alternative SP foods is expected to continue its upward trend as consumers become more health conscious [14]. Literature data on SP phytochemistry emphasizes that its therapeutic virtues are strongly linked to its phenolic compounds antioxidant activity [17].

Overall, this study aimed at investigating the phytochemical composition of two tubers namely CP (*Solanum tuberosum* L.) and SP (*Ipomoea batatas* L.) planted in Morocco, to highlight their nutritional properties (macronutrients and micronutrients), and, finally, to determine their antioxidant and in vitro anti-inflammatory activities. The projected results will make it possible to valorize nutritional and therapeutic virtues of SP in comparison with CP, and also the recommendations and practical advice to be addressed to local consumers regarding SP intake advantages.

2 Material and Methods

2.1 Biological Material

Samples of SP (*Ipomoea batatas* L.), from the Convolvulaceae family planted in Morocco, and CP (*Solanum tuberosum* L.), belonging to the Solanaceae family (known as the most consumed vegetable), were collected in the markets of Fez city in Morocco. The taxonomic position of the studied plants (SP and CP) was confirmed by the National Agricultural School of Meknes (Morocco). On arrival, samples of both varieties were washed, dried and kept at 4 °C for subsequent analysis. Potatoes samples were cleaned with tap water before being rinsed with distilled water. After removing any residual distilled water from the surface with absorbent paper, both tubers were peeled, cubed and ground in stomacher (® 400 Circulator, Villanova, USA). The stomacher was cleaned before processing each tuber. Samples were grinded rapidly to avoid enzymatic degradation. The grindings were dried at 70 °C to constant weight, then dry-ground and stored in a dark place.

The obtained powder was subjected to phytochemical analysis, nutritional and biological activities determination. An index called fortification degree (FD) was introduced in this study to facilitate the comparison of parameters results. Fortification degree is the ratio of each studied parameter (carbohydrates, proteins, lipids, vitamin C, carotenoids, phenolic compounds, and flavonoids) in SP variety divided by that of CP (Eq. 1):

$$FD(X) = \frac{SP(X)}{CP(X)} \quad (1)$$

2.2 Water Content and Macronutrients Evaluation

2.2.1 Water Content

The water content (WC), as physicochemical parameter calculation of the studied tubers, was carried out by putting 100g of the analyzed samples in an oven (Binder, BD, Saint-5Denis, France) at 60–65 °C until weight constancy. Water contents were determined according to the following equation (Eq. 2):

$$WC(\%) = \frac{IW - FW}{IW} * 100 \quad (2)$$

where; *WC* Water Content, *IW* Initial Weight, *FW* Final Weight.

2.2.2 Total and Reducing Sugars

Determination of total sugars (TS) of the two studied tubers was carried out by the Anthrone colorimetric method as previously reported [18]. Absorbance was determined by spectrophotometer (Humeau UV-21 UV/Visible, Nantes, France) was determined at 580nm wavelength, with a linear calibration curve of sucrose (Sigma, Paris, France) defined as: $OD_{TS} = 5.38 \times C + 0.11$, where OD_{TS} is total sugars optical density, while C is their concentration in g/L, and a linear correlation coefficient of $R^2 = 0.99$. The linear range calibration was attained for sucrose concentrations from 0 to 1g/L.

Reducing sugars (RS) were evaluated by 3,5-dinitrosalicylic acid [DNS, (Sigma-Aldrich, Taufkirchen, Germany)] colorimetric method [19], where optical density was evaluated at 540nm wavelength with a linear calibration range (glucose) defined as: $OD_{RS} = 6.50 \times C + 0.03$, where OD_{RS} is reducing sugars optical density, and C is their concentration in g/L, and a linear correlation coefficient of $R^2 = 0.99$. The linear range calibration was attained for glucose concentrations from 0 to 1g/L. Therefore, non-reducing sugars (NRS) are equal to the difference between TS and RS.

2.2.3 Protein Content

Protein determination in analyzed samples was done by the biuret method [20] and the Lowry method [21]. Regarding the biuret method, a calibration curve using bovine serum albumin (BSA, (Merck, Darmstadt, Germany)) was used, the optical density was assessed at 540nm, which resulted in a linear calibration range defined as $OD_{Prt} = 0.04 \times C + 0.01$, where OD_{Prt} is proteins optical density, and C is their concentration in g/L, and a linear correlation coefficient of $R^2 = 0.99$. The linear range calibration was attained for BSA concentrations from 0 to 0.1g/L. Regarding total proteins determination by Lowry's method, the optical density was assessed at 700nm and the obtained linear calibration range (BSA) was $OD_{Prt} = 1.63 \times C + 0.003$. The linear correlation coefficient (R^2) was 0.99 and the linear range was attained for BSA concentrations from 0 to 0.1g/L.

2.2.4 Lipid Content

Lipids in the two studied tubers were quantified after extraction, done at 25 °C, with chloroform and methanol (2:1 chloroform–methanol (v/v), by the method of Smedes and Thomasen [22]. The dried biomass (5g) was mixed with 25 mL of methanol (Sigma-Aldrich, Darmstadt, Germany), 12.5 mL of chloroform (Sigma-Aldrich, Darmstadt, Germany) and 5 mL of deionized water. The mixture was subjected to ultrasonic energy (Fisherbrand™ model 12 sound level meter, Illkirch-Graffenstaden, France) during 40 min. Chloroform (12.5 mL) and a solution of 1.5% (w/v) sodium

sulphate (12.5 mL) (Sigma-Aldrich, Darmstadt, Germany) was added to the mixture and sonicated (Sigma-Aldrich, Darmstadt, Germany) for 20 min.

2.3 Phytochemical Screening

2.3.1 Phenolic Compounds

Phenolic compounds were determined by the Folin-Ciocalteu's method, where gallic acid (GA: BOC Sciences, New York, USA) were used as standard. Phenolic compounds extraction from the tubers was done in an aqueous extract produced by maceration of 5g of each dried sample for 2h at room temperature. Samples were spectrophotometrically analyzed at 760nm, which resulted in a linear calibration curve defined as $OD_{PC} = 26.923 \times C$. The linear correlation coefficient (R^2) was 0.99 and the linear range calibration was attained by gallic acid (from 0 to 200 mg/L). Phenolic compounds content were expressed in gallic acid-equivalent (mg GAE/100g) of dry-weight tubers [23].

2.3.2 Exclusion Chromatography

Phenolic compounds size distribution (from monomers to polymers) in SP and CP ethanolic extracts was determined by using Sephadex gel exclusion chromatography. A glass column (50 cm long × 2.5 cm internal diameter) containing Sephadex G50 (stationary phase) and lithium chloride solution was used to interpret the results for the biological activities achieved (antioxidant and anti-inflammatory) as a function of the phenolic compounds characterized by their molecular weight (MW). The latter is used as the mobile phase (5 mM NaOH and 2.5 mM LiCl) to recover fractions (2 mL) from the chromatographic column programmed at a flow rate of 1 mL/min. Fractions absorbance (380nm) of the was assessed using a spectrophotometer (Zuzi 4255/50; Auxilab S.L., Navarre, Spain) according to the method described by Himmel et al. [24]. The column was calibrated with phenol (Sigma Aldrich, Munich, Germany) and quercetin (Sigma Aldrich) for monocyclic and polycyclic phenolic compounds fractions localizations respectively.

2.3.3 Flavonoid Content

Flavonoids were determined by the aluminum chloride ($AlCl_3$) method, where quercetin was used to develop the linear calibration range (0, 1, 2, 3, 4 and 5 µg/mL) at 510 nm expressed as: $OD_{Fl} = 0.2394 \times C$. The linear correlation coefficient (R^2), between optical density (OD) and quercetin concentration (C), was 0.99 and the linear range calibration was attained for quercetin (BOC Sciences, New York, USA) concentrations from 0 to 50 µg/mL. Flavonoids content was expressed in quercetin-equivalent per 100 g (mg QE/100g DW). All analyses were performed in triplicate [25].

2.4 Micronutrient Analysis

2.4.1 Vitamin C

One hundred grams of the tubers were cut into small pieces, ground (Homogenizing grinder Stomacher 400, Geneve, Switzerland) in 100 mL of distilled water then filtered. The obtained liquid aliquot (10 mL) was introduced into a beaker to which 2 drops of starch indicator (10%) (Sigma-Aldrich, Darmstadt, Germany) were added. Rapid dosage of this solution was done with iodine (I_2) C = 0.01M (Sigma-Aldrich, Darmstadt, Germany) [26]. Vitamin C dosage was also carried out by an indirect method using sodium thiosulfate ($Na_2S_2O_3$) (Sigma-Aldrich, Darmstadt, Germany) according to Wapwera et al. [27].

2.4.2 Carotenoids

Carotenoids content was determined on an aliquot of the hexane (Sigma-Aldrich, Lyon, France) extract according to the spectrophotometric method (Humeau UV-21 UV/Visible, Nantes, France) cited by Lee et al. [28] with optical density at λ = 450nm in the spectrophotometer. Carotenoids was measured using a carotene molar extinction coefficient ε_o (λ) = 2505L.mol^{-1}. cm^{-1}. In parallel, a linear calibration curve defined as $OD_{Cat} = 13.45 \times C$ was developed based on β-carotene (Sigma-Aldrich, Darmstadt, Germany). β-carotene was used as blank to increase analysis accuracy. The linear correlation coefficient (R^2) was 0.99 and the linear range calibration was attained for β-carotene concentrations (0, 1, 2, 3, 4, and 5 µg/mL). All analyses were performed in triplicate.

2.5 Antioxidant Activity

2.5.1 Extracts Preparation

For antioxidant activity evaluation, obtained extracts by three solvents of increased polarity were used, viz. n-hexane (Sigma-Aldrich, Darmstadt, Germany), ethyl acetate (Sigma-Aldrich, Darmstadt, Germany) and ethanol (Sigma-Aldrich, Darmstadt, Germany). One hundred grams of each sample were grinded (Homogenizing grinder Stomacher 400, Geneve, Switzerland) and filtered (inox sieve 0.1mm) then placed in an extraction cartridge and coupled into a 500 mL Soxhlet extractor (Wenk LabTec, Germany). After 36 extraction cycles with 250 mL of each tested solvent, the extracts were concentrated under reduced pressure with a Rotavapor (BUCHI R-100, Bernolsheim, France). Obtained residues were aliquoted and kept at −20 °C until analysis.

Methanol and ethanol were used as blanks for DPPH and TAC tests, respectively.

2.5.2 In Vitro Antioxidant Activity

Obtained residues antioxidant activity were assessed by using 2,2-diphenyl-1-picrylhydrazyl [DPPH, (Sigma-Aldrich, Darmstadt, Germany)] test [29]. Phenolic compounds extracts (2.5 mL with 0.2 mg/mL) were mixed with 2.5 mL of DPPH methanolic solution (0.04 mg/mL). After vortexing (IKA-Werke, Staufen, Germany), sample tubes were hired in darkness for 30 min. After that, optical density was assessed at 517nm. Tests were done in triplicate per concentration. Finally, antioxidant activity was extracted from the following formula (Eq. 3):

$$\text{Antioxidantactivity}\% = \frac{DPPHAbs_{517} - \text{Sample}Abs_{517}}{DPPHAbs_{517}} * 100 \quad (3)$$

where:

DPPH Abs517 is the absorbance of DPPH at 517 nm,

Sample Abs517 is the absorbance of sample extract at 517 nm.

2.5.3 Total Antioxidant Capacity (TAC)

Total antioxidant capacity was evaluated by the phosphomolybdenum complex method [30]. The principle of the technique is based on phosphomolybdate reduction in the presence of antioxidants, resulting in the formation of a green complex. A sample extract (0.005g) was added to 25 mL of ethanol 70% (v/v) (Sigma-Aldrich, Darmstadt, Germany) and homogenized in a vortex. Hydroethanol extracts aliquots (300 µL) maintained at a concentration of 200 µg/mL were mixed with 3 mL of the reagent in an amber vial, chiefly 0.6 mol/L sulfuric acid (Sigma-Aldrich, Darmstadt, Germany), 28mmol/L sodium phosphate (Sigma-Aldrich, Darmstadt, Germany) and 4 mmol/L ammonium molybdate Sigma-Aldrich, Darmstadt, Germany). These vials were incubated in a thermal block (LabBox, Paris, France) at 95 °C for 90 min. After cooling, optical density was read at 695nm. The blank containing 1 mL of reagent solution and a volume of 70% (v/v) ethanol was used and incubated under the same conditions.

2.6 In Vitro Anti-Inflammatory Activity

The in vitro anti-inflammatory activity of phenolic compounds extracts of SP and CP was assessed by protein denaturation using the method reported by Benkiran et al. [31]. In this study, we adopted as a positive control Sodium Diclofenac, recognized as a product with very high anti-inflammatory potential. Ethanolic extract was used in this experiment as it is readily soluble in the phosphate buffer used to study anti-inflammatory activity. The reaction medium is a mixture of 2 mL ethanolic extract isolated from the two studied tubers, maintained at a concentration range from 100 to 300 µg/mL, with 2.8 mL phosphate buffer (pH 6.4). To this mixture was added 2 mL of freshly prepared egg albumin (protein), then incubated at 27 °C for 15 min. Denaturation was carried out by treating the mixture at 70 °C for 10 min. After cooling, optical density was assessed at 660nm using bidistilled water as a control. Protein denaturation inhibition expressed as % was deduced from the following formula (Eq. 4):

$$\%\text{inihibition} = \frac{Ac - A}{Ac} * 100 \quad (4)$$

where; A = Tested sample absorbance, and Ac = Control absorbance.

2.7 Statistical Analysis

To compare means of obtained results, the student's test with 95% confidence interval was used. Moreover, in each independent variable (observation), 3 replicates of samples were performed and 3 repetitions (n = 3) of analyses per replicate were analyzed. All data are expressed as mean values ± standard deviation. Standard deviations have been visualized in the figures using Prism Pad 9 software.

3 Results and Discussion

3.1 Water Content and Macronutrient Composition

3.1.1 Water Content

Water content is a physicochemical parameter widely used to characterize plant products freshness. Results showed that SP is less rich in water (72%) than CP (86%). This means that *Ipomoea batatas* L. may be less rich in substances that act to supplement cell osmotic pressure (osmoticum) when compared to *Solanum tuberosum,* which could be rich in some minerals such as potassium (K). Certainly, this element has a significant effect on plant growth, yield, product quality and stress resistance. For example, *Solanum tuberosum* L. crops require large amounts of potassium to achieve maximum quality and quantity yield [32]. These results are in line with the work carried out in China on 81 SP varieties, which shows that water content average is around 70.8% [33]. However, our results for water content in CP are higher

than those obtained by Dereje et al. [34], which represent 80%. This water parameter is strongly influenced by genotype and irrigation method [35]. Analytical results regarding water and macronutrient contents (%) in SP and CP are summarized in the following table (Table 1).

3.1.2 Total and Reducing Sugars

Total and reducing sugars content in CP and SP tubers are depicted in Table 1. Accordingly, CP contain higher levels of total sugars (16.65g/100g DW) than in SP (12.47g/100g DW). The fortification degree ratio (FD = SP/CP) (Eq. 3) corresponds to 0.75 and 0.84 for total and reducing sugars, respectively. Our results centered on total sugars are significantly higher than those found in the literature by Krochmal-Marczak et al. [36], who showed that its content in SP is equal to 7.83g/100g DW through their study conducted on 5 SP varieties in Central Europe. Our results also significantly exceed those of Saar-Reismaa et al. [37], who revealed that total sugars value in potatoes is equal to 2.16g/100g DW in 21 potato varieties in Estonia. Total sugars are largely influenced by storage and processing, especially at temperatures below 10 °C [38].

The sweet taste of SP is due to the production of sucrose in the SP [39]. Thus, it can be suggested from obtained results (Table 1), that SP consumption, instead of the CP, would be very beneficial for low sugar diets or diabetics. In fact, several studies have shown that SP flesh aqueous extract has an antidiabetic effect by its ability to reduce glucose levels in blood and decrease protein and lipid glycation [40]. As a matter of fact, SP have been considered as nutraceuticals that control blood sugar and glycated hemoglobin in type 2 diabetics [41].

3.1.3 Protein Content

As shown in Table 1, the fortification degree varies from 1.56 to 1.78 and SP contain a higher protein level (5.21g/100g DW) when compared to protein amounts recorded in CP (2.93g/100g DW). Our findings are similar to those reported in the literature, that confirmed the presence of significant protein contents in SP [42]. Our results correlate with those previously published by Arshad et al. [43], who stated that protein contents are of the order of 5.56 g/100g DW in SP and 2.06 g/100g DW in CP. According to the literature, SP proteins (SPPs) are mainly composed of sporamin monomeric forms, sporamin A and B that have similar amino acid compositions with a characteristic arrangement [44]. It should be highlighted that SP peel proteins have a higher nutritional value, both qualitatively and quantitatively, than other parts of the plant, but they are often discarded as industrial solid waste during starch manufacturing. Therefore, it would be wise to use SP peels in the formulation of new functional ingredients as value-added agri-food products, which would be preferable for local and sustainable economic development [45].

Table 1 Water and macronutrient contents (%) in analyzed SP and CP samples (dry weight)

Content (%)	SP	CP	FD
Water content	72	86	
Reducing sugars	2.53 ± 0.13	2.13 ± 0.11	0.84
Non-reducing sugars	14.12 ± 0.70	10.34 ± 0.51	0.73
Proteins (Biuret's method)	2.93 ± 0.15	5.21 ± 0.26	1.78
Proteins (Lowry's method)	2.79 ± 0.17	4.36 ± 0.23	1.56
Lipids	0.11 ± 0.01	0.29 ± 0.02	2.68

Note: *SP* Sweet potato, *CP* Conventional potato, *FD* Fortification degree

3.1.4 Lipid Content

Fat content in analyzed samples are tabulated in Table 1. It can be noted that SP contain higher lipid concentrations (0.3%, w/w DW) than those found in CP (0.1%, w/w DW). Several studies have confirmed the presence of bioactive lipids in CP such as fatty acids, glycolipids, phospholipids, phytosterols, tocopherols and carotenoids, which can reach up to 0.5% (DW) of their fresh weight [46]. Referring to a comparative study between CP and SP conducted by Arshad et al. [43], our results are much lower, where SP lipids represent 0.86g/100g DW and CP lipids represent 1.62g/100g DW.

Lipids are known to exhibit various physiological functions, as well as vital biological properties such as hypolipidemic, anti-atherosclerotic, antimicrobial, anti-inflammatory, anticancer and antidiabetic activities [47]. In fact, it was well known that they can improve eyesight and memory, especially to promote the growth and development of infant brain cells [48]. Furthermore, fatty acids, as functional lipid ingredients [49], play an important role in cell membrane fluidity.

3.2 Micronutrient Composition

3.2.1 Vitamin C

Vitamin C levels determination in analyzed samples was performed quickly to avoid its oxidation. Iodine (I_2) assay reveals higher vitamin C concentrations in SP when compared to CP (Table 2). Vitamin C levels reached 471.33 ± 23.57 mg/100g DW in SP and 26 ± 1.30 mg/100g DW in CP. Similarly, recorded concentrations by indirect method using $Na_2S_2O_3$ also show higher vitamin C levels in SP, with average values of 26.33 ± 1.32 mg/100g DW

Table 2 Micronutrient levels and phytochemicals (mg/100g DW) in analyzed SP and CP samples

Content (mg/100g)	SP	CP	FD
Vitamin C (Direct method)	471.33 ± 23.57	26 ± 1.30	18.13
Vitamin C (Indirect method)	440 ± 22.00	26.33 ± 1.32	16.71
Carotenoids	212 ± 10.60	5.96 ± 0.30	35.57
Phenolic Compounds (GAE)	130.11 ± 6.51	47.55 ± 2.38	2,74
Flavonoids (QE)	85.03 ± 4.25	0.50 ± 0.03	170

Note: *SP* Sweet potato, *CP* Conventional potato, *FD* Fortification degree

for CP and 440 ± 22 mg/100g DW for SP (Table 2). Our results concerning vitamin C content in SP (471.33 ± 23.57 mg/100g DW) far exceed those (160 ± 3.12 mg/100g DW) found by Babalola and al. [50]. The same authors reported that vitamin C levels in CP (79.3 ± 2.14 mg/100g DW) are higher than those found in the present study (26.33 ± 1.32 mg/100g DW) [50]. These results confirm the SP richness in vitamin C. Indeed, significant amounts of vitamin C have been reported in SP varieties, which suggests its use as a promising source of dietary micronutrients with antioxidant activity [51]. Analytical results regarding micronutrients and phytochemicals in SP and CP are represented in Table 2.

3.2.2 Carotenoids

As summarized in Table 2, carotenoid levels expressed in β-carotene was 5.96 mg/100g DW, in CP, and 212 mg/100g DW, in SP. These results confirm the latter richness in carotenoids, which can be responsible for its nutritional value and its beneficial health effects for consumers [52]. Our result reflects a high carotenoid content in SP when compared to that found by Johnson et al. [53], who worked on five Australian SP cultivars with carotenoid contents ranging from 1.1 to 52.8 mg/100g DW. Similarly, our result in relation to potatoes carotenoid content is much higher than the values recorded in 60 potato varieties according to the study carried out by Valcarcel et al. [54], whose values range from 0.03 to 0.17 mg/100g DW. SP varieties are characterized by different colors (white, cream, yellow, orange and purple), because they are containing different types of carotenoids [53]. For example, the cultivar '*Bellevue*' contained highest β-carotene content (48.2 mg/100g DW), followed by '*New Orleans*' and '*Beauregard*' with β-carotene contents of 43.0 and 34.0 mg/100g DW respectively. On the other, purple and white cultivars contained low amount of modified β-carotene (0.1–0.2 mg/100g DW). In raw SP, trans- and cis-β-carotene percentage ranged from 0.38 to 7.24 mg/100g FW. In general, cis-β-carotene content is very low or insignificant in SP, although white or yellowish-fleshed varieties have significantly more cis-β-carotene than orange varieties [55]. Among selected SP varieties, "*BARI SP8*" contained a significantly lower carotenoids amounts (7.24 mg/100 g FW), followed by "*BARI SP2*" (6.38 mg/100 g FW), "*BARI SP9*" (4.61 mg/100 g FW), "*BARI SP4*" (3.72 mg/100 g FW), "*BARI SP7*" (3.01 mg/100 g FW) and "*BARI SP5*" (2.12 mg/100 g FW) [56]. Other studied varieties had relatively lower carotenoid contents (ranging from 0.39 to 8.82 mg/100 g) than the *OFSP* variety. On the other hand, another study carried out on the same variety showed that it contained high quantities of carotenoids (between 7.91 and 12.85 mg/100 g DW), and was recognized as a valuable source of β-carotene [56].

Mihaela et al. [57] showed that total carotenoid contents in five varieties fresh tissues of SP with different flesh colors, is higher in orange SP (*Juhwangmi*), followed by yellow SP (*KSP1* and *KSC1*) and white SP (*Yulmi* and *Hayanmi*). Carotenoids were found in all SP samples, ranging from 11.50 mg/100g DW in white SP to 34.94 mg/100g DW in orange SP. β-carotene content varied according to the variety, with values of 7.275, 1.075, 47.2, 40.45 and 99.95 mg/g FW (different varieties). Carotenoid levels were generally highest in peeled and freeze-dried, orange-fleshed SP roots (28.19 mg/100g DW), followed by yellow-fleshed roots (2.62 mg/100g DW), with light yellow-fleshed (1.69 mg/100g DW) and purple-fleshed (0.2 mg/100g DW) SP roots, with β-carotene predominating in all these varieties. The β-carotene content of the raw SP used to make the final product was 8.18 ± 66 mg β-carotene per 100 g fresh SP, whereas the predicted value was 17.296 mg β-carotene per 100 g DW. The existence of some rare carotenoids in certain Japanese varieties grown in the USA (cultivars *WS* and *W71*) [58]. In the later varieties, the authors highlighted the compounds β-carotene-5,8-epoxide (9.4 and 4.6% of total carotenoids, respectively), β-carotene-5,6,5′,8 ′-diepoxide (35.7 and 9.2%, respectively) and β-carotene-5,8,5′,8′-diepoxide (25.1 and 13.8%, respectively). These typical carotenoids had previously been identified in a Japanese "*Benimasari*" variety. The latter remains genetically far from the WS and W71 varieties, which contain carotenoids with a 5,6-epoxy-β ring and/or a 5,8-epoxy-β ring in their struture.

3.3 Phytochemical Screening

3.3.1 Phenolic Compounds

Phenolic compounds quantity and quality play a very important role in human health. As shown in Table 2, the phenolic compounds recorded in SP greatly exceed those of CP and reach 130.11 mg GAE/100 g DW while CP reach only 47.55 mg GAE/100 g DW. These results are significantly lower than those found by Arshad et al. [43] who reported that the phenolic composition of SP and potato varieties grown locally in Pakistan contain 927 mg

GAE/100 g DW and 291 mg GAE/100 g DW respectively. Previous studies showed the SP potential as medicinal foods due to their health benefits, phytochemical composition, mainly phenolic compound contents [57, 58]. The flavonoid and phenolic compound ratio F/PC is essential in SP (65%) when compared to CP (1%). Thus, phenolic compounds obtained from SP are higher when compared to those of CP in terms of quality and quantity [59].

3.3.2 Phenolic Compounds Gel Filtration Chromatography

Exclusion chromatography performed on Sephadex G50 gel was used to identify phenolic compounds (polymers, oligomers and monomers) distribution in ethanolic extracts of SP and CP. The obtained results are illustrated in Fig. 1. The latter shows phenolic extract richness in SP (upper curved) when compared with CP (lower curved). In SP, polymeric phenolic compounds are localized in fractions 4 to 13, whereas in CP, polymeric phenolic compounds are found in fractions 6 to 13 with a low amplitude. With regard to oligomeric compounds, phenolic compounds are more abundant in SP than in CP (almost double). Monomeric phenolic compounds were almost identically distributed in the two studied tubers, with a higher intensity in SP profile.

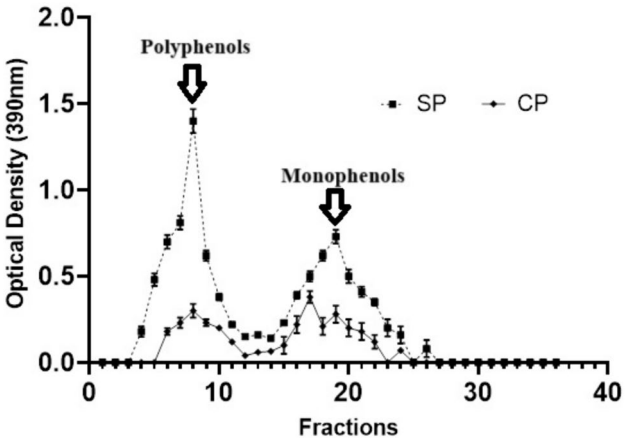

Fig. 1 Molecular weight distribution of phenolic compounds extracted from studied tubers by Sephadex G50 gel exclusion chromatography

3.3.3 Flavonoids

As shown in Table 2, we can notice that total flavonoids calculated from aqueous flesh extracts of the two samples show high concentrations in SP (85.03 mg QE/100g DW), which largely exceed those obtained in CP (0.5 mg QE/100g DW). The richness of SP in flavonoids would be beneficial for human health [60]. Flavonoid contents found in the present study are much lower than those reported in Pakistan [43]. These authors reported flavonoid contents were around 1901 mg QE/100g DW in SP and 238 mg QE/100g (DW) in CP. The observed discrepancy between the data obtained and those described in the literature may be due to the particularities of the biotope, to the local climatic conditions (temperature and rainfall), as it may be due to the local ploughing conditions (use of fertilizers, etc.).

SP phenolic compounds in fall into two main categories [61]. Flavonoids are mainly found in SP tuberous roots as pigments and can be classified by purple, orange and yellow color. SP phenolic acids consist of a mixture of derivatives of caffeic acid (CA) and caffeoylquinic acid (CQA) [62]. However, their content is most abundant in leaves and the amount contained in the stems, petioles, and tubers is low [63]. Indeed, regular consumption of SP could have different therapeutic virtues including the fight against certain nutritional deficiencies, but also for the protection of the organism against chronic diseases. These recommendations have already been affirmed by previous authors [64, 65].

3.4 Antioxidant Activity

The antioxidant activity of n-Hexane, ethyl acetate and ethanol extracts of studied samples using free radical DPPH and TAC reagent methods are depicted in Table 3. As may be seen, the antioxidant activity values are considered high in SP (23.8 ± 1.7% DPPH) and (89.07 ± 6.23 mg AAE/g TAC) when compared to those of CP (16.36 ± 2.14% DPPH) and (45.23 ± 3.17 mg AAE/g TAC) in the ethyl acetate extract. Recorded results in the study conducted by Arshad et al. [43] revealed that the SP and potato antioxidant activity evaluated by the DPPH method using a methanolic extract is in the order of 39.12 ± 0.33% and 31.67 ± 0.30% respectively.

The high antioxidant activity obtained with hexane extract is positively correlated with the lipid fractions found in SP, as shown in Table 3. These non-polar molecules

Table 3 Mean values and standard deviations (mean ± STDV) of the antioxidant activity using the DPPH (%) and total antioxidant capacity (TAC) (mg AAE/g) methods in analyzed potato varieties

Samples	SP		CP	
Sample extract	DPPH (%)	TAC (mg AAE/g)	DPPH (%)	TAC (mg AAE/g)
n-Hexane	17.12 ± 1.20	53.45 ± 3.74	12.51 ± 0.87	36.21 ± 2.53
Ethyl acetate	23.80 ± 1.70	89.07 ± 6.23	16.36 ± 2.14	45.23 ± 3.17
Ethanol	15.82 ± 1.10	26.85 ± 1.88	13.12 ± 0.93	17.50 ± 1.22

exhibit significant antioxidant activity. On the other hand, ethanolic extracts containing polar molecules also exhibit significant antioxidant activity strongly correlated to flavonoids fractions found in SP. Finally, the ethyl acetate extracts of intermediate polarity also exhibit significant antioxidant activity [66].

The antioxidant activity of ethanolic extract is higher in SP than CP. It was reported that certain phytochemical components of SP (quinic acid, caffeic acid, chlorogenic acid, and isochlorogenic acid), are known with their pharmacological activities that could be beneficial for human health, with antioxidant, antidiabetic, healing, antiulcer, and antibacterial effects, etc. [65]. It was highlighted also that theses bioactive compounds may play a vital role in promoting health by reducing OS and free radical damage [67].

It can be noted that the antioxidant activities of tested extracts represented in Table 3 are proportional to fat, phenolic compounds and flavonoids content (Table 1 and Table 2). These bioactive compounds were found in considerable concentrations in SP. The antioxidant activity was used in this study to indirectly translate other biological activities not introduced in the present work since they are related. This is the case, for example, of the anticancer activity, which is strongly correlated with antioxidant activity [68].

3.5 In Vitro Anti-Inflammatory Evaluation

SP and CP extracts with concentrations ranging from 100 µg/mL to 300 µg/mL showed significant inhibition of protein denaturation (IPD) (egg albumin) in a dose-dependent manner. The *invitro* anti-inflammatory activity of SP ethanolic extract is comparable to that of diclofenac sodium. A noticeable difference was observed between the *in vitro* evaluated activities obtained from the two studied tubers (SP and CP). A significant difference in the inhibition of thermally-induced protein denaturation was observed in SP extracts when compared to CP and standard drug (Sodium Diclofenac) at a concentration of 100 µg/mL, although at a concentration of 200 and 300 µg/mL, SP extract inhibition activity and Sodium Diclofenac were comparable and superior to that obtained with CP. The inhibitory effects of SP and CP ethanolic extracts on protein denaturation are summarized in Table 4.

Table 4 Effects of SP and CP extract on *invitro* anti-inflammatory activity

EPCC (µg/mL)	IPD SP	IPD CP	IPD Diclofenac sodium
100	79 ± 2.20	53.40 ± 3.50	85.30 ± 1.80
200	91.50 ± 2.30	77.80 ± 1.80	104 ± 2.60
300	102 ± 2.53	89.70 ± 2.90	102 ± 3.50

Note: *IPD* inhibition of protein denaturation (%), *EPCC* concentration of phenolic compounds in ethanolic extracts of SP and CP

4 Conclusion

The present study, focused on SP (*Ipomoea batatas* L.) and CP (*Solanum tuberosum* L.) nutritional value, showed notable differences between the two tubers. Water and total sugar contents are higher in the CP than in SP. Nevertheless, SP flesh contains more proteins and lipids. Our results also showed a significant presence of bioactive molecules (phenolic compounds, carotenoids and vitamin C) as well as higher antioxidant activity in SP when compared to CP. The biological activities tested (antioxidant and anti-inflammatory) are well positively correlated with SP polymeric phenolic compounds. This has allowed us to recommend SP consumption by local population and their adoption as vegetable of choice, given their great nutritional properties in addition to their various health benefits. Finally, on the economic level, and according to the technical–economic sheets, the weight yield of SP is 30 T/ha/year, which is lower than that of CP (40 T/ha/year). However, the economic gain from the sale of SP is 2560 MDH (250 US dollars)/ton, which is higher than that of CP 1600 MDH (160 US dollars)/ton, and therefore the production of SP remains more economically advantageous, which supports the recommendation to promote the cultivation and consumption of SP at the national level given its nutritional and therapeutic properties, and its economic value.

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Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare that there are no conflicts of interest related to this article.

Ethical Statement/Clinical Trial Registration Number/Informed Consent Not applied.

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