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Pre-Soaking cum Boiling Effects on Oxalate Content and Acridity of Elephant Foot Yam Corm

Anuj Kumar*, Pola Ramakumar, Ashok Patel, Vijay Kumar Gupta and Ashish Kumar Singh

ICAR-National Dairy Research Institute, Karnal 132001, Haryana

Corresponding author: Anuj Kumar, e-mail: anuj19.ak@gmail.com

Abstract

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson; EFY) has not been fully exploited due to the presence of oxalates which are anti-nutritional and responsible for causing acridity (itching-cum-burning) sensation in soft tissues. To realize the full benefits of EFY, it is necessary to explore the reduction in oxalate content. Soaking in alkali (A) (0.01, 0.05, 0.10%), saline (S) (2, 6, 10%) and acidulated-saline (P) (pH 3.5) followed by boiling for 30 min did not significantly reduce oxalate content. Oxalate content were 91.87-94.61, 94.60-98.58, 94.61-96.43 mg $100g^{-1}$ and tactile acridity score were 0.45-1.03, 1.05-1.68, 1.05-1.45 for A, S and P treatments, respectively. Alkaline presoaking caused reduction in the acridity sensation, while soaking in salt solution enhanced the acridity. Alkaline soaking treatment caused significant darkening of elephant foot yam. Cooking rather than salt treatments reduced oxalate significantly, presumably due to leaching and hydrothermal degradation of oxalates. Proper cooking of EFY is desirable to reduce oxalates before consumption.

Key words: *Amorphophallus paeoniifolius*, oxalate, acridity, elephant foot yam

Introduction

Elephant foot yam (*Amorphophallus paeoniifolius*) (EFY) corm is a very good source of starch (13.93-21.53%) and it contains small amount of protein (0.84-2.60%), sugar (0.55-1.77%) and fat (0.07-0.37%) (Chhattopadhyaya et al., 2010). EFY possesses various bio-activities and is used to treat several medical conditions (Ayurvedic Pharmocopiea of India, 2007; Yabesh et al., 2014).

Acridity, an itchy sensation felt in the mouth and throat, is a problem encountered upon consumption of EFY corm (Kumar et al., 2013). The corms and leaves of edible aroids are acrid and consuming them without proper processing may cause organoleptic and health problems (Osisioguet al., 1974; Sanz and Reig, 1992; Holmes et al., 1995; Nelson et al., 2007).Oxalates deposited in plant tissues, are the cause of the itchy sensation (Bradbury and Nixon, 1998). When in sufficient quantity, these crystals cause mechanical abrasion of the mucous membranes and cause irritation and a burning sensation in the mouth and throat (Lebot, 2009). The mechanical release of needle shaped raphides causes the injury (Rizzini and Ochioni, 1957; Gardner, 1994). Further, deposition of calcium oxalate crystals in the kidneys (Williams and Wandzilak, 1989), occurrence of renal stones and reduction in bioavailability of Ca, Fe, Zn, Mg are also involved in depression of cerebral functions and seizures (Chen et al., 2002). The health concerns regarding oxalates and acridity has contributed toward underutilization of EFY. Reducing oxalate content in the human diet helps to prevent oxalate mediated hyperoxaluria (Attala et al., 2014).There are some released varieties of EFY which have acridity at very low/ tolerable level. The oxalate content in the corm of released varieties of EFY are 0.03 mg 100 g^{-1} in var. *Gajendra*, 11.59 g 100 g^{-1} in var. Bidhan Kusum (BCA-1) and 0.9 g 100 g^{-1} in var. NDA (James George et al., 2012). But, local varieties having high acridity, are also often available in the market. Therefore, the present study was undertaken to examine the effect of soaking in alkali, saline, or acidulated-saline combined with cooking in mitigating acridity-oxalate problems in EFY.

Materials and Methods

Corms of local elephant foot yam landrace were purchased from a vegetable market in Karnal, Haryana, India. The corms were diced in 2 cm cubes, dipped in 0.1% potassium metabisulphite solution for 5 min, blanched in excess boiling water for 10 min and then cooled immediately with water. The blanched cubes were allowed to surface dry, packed in nylon pouches (Kumar et al. (2013, and stored in a freezer (-18°C) until needed. The frozen EFY cubes were thawed overnight in a refrigerator5 ± 1°C. EFY cubes were soaked in soak solutions, (1:6 yam: water (w/v)) viz., 0.01, 0.05 or 0.1% sodium hydroxide solution; 2,6 or 10% sodium chloride solution; or 2,6 and 10% sodium chloride solution acidulated to pH 3.5 (using citric acid) for 60, 90 or 120 min. After pre-soaking, the water was drained and cubes were washed in running tap water. The cubes were cooked in boiling water (30 min), made into paste and evaluated.

Oxalate was determined from the paste according to Okombo and Liebman (2010) with minor modifications described by Kumar et al. (2016) and analyzed using an oxalate kit (Trinity Biotech Co., Wicklow, Ireland).

Hand sensed acridity was assessed by a tactile technique. Panel members were selected from the division, and ranged in age from 23-28 years, using a semi-structured intensity rating scale (Kumar et al., 2013). Panel members were instructed to apply the EFY paste on the inner part of the forearm and the intensity of acridity-tingling sensation determined and recorded on the acridity evaluation card. The descriptors for the tactile acridity score were: 0 = no acridity, 1 = slight acridity, 2 = moderate acridity, 3 = definite acridity and 4 = extreme acridity. For mouth feel acridity score, a 10% EFY paste-milk mix (w/v) was prepared using a hand blender. The mix was evaluated for acridity by a semi-trained panel selected from the division on a 9-point hedonic scale.

Hunter L*, a* and b* values of the EFY paste were measured using a Colorflex®spectro-colorimeter (Hunter Lab, Reston, VA) and converted to whiteness index (WI).

The data obtained were analysed by analysis of variance (ANOVA) IBM SPSS Statistics version 20. Significant differences between means were determined using Tukey's honestly significant difference (HSD) test.

Results and Discussion

The oxalate content of paste obtained from alkali soaked, cooked EFY was not affected by alkali concentration or soaking duration(Fig. 1a). Kumoro et al. (2014) reported a reduction of oxalate content due to sodium bicarbonate treatment and time giant taro. Kumar et al. (2013) reported a positive effect of alkali concentration in reducing oxalate, but at slightly higher pre-soaking temperatures (40-50°C) than used in the present study. Cooking is known to reduce oxalates in food due to thermal degradation and consequent leaching into cooking water (Savage et al., 2000). Chai and Liebman (2005) reported boiling significantly reduced the soluble oxalate content by 30-87% in various vegetables. Boiling is effective in reducing oxalates in various tuber crops (Wanasunder and Ravindran, 1992; Iwuoha and Kalou, 1995; Bhandari and Kawabata, 2006; Catherwood et al., 2007; Hang et al., 2013). In the present study, oxalate content in EFY soaked in salt solution (NaOH, NaCl) was not affected by salt level or soaking duration. However, boiling effectively reduced oxalates in EFY corm.

Hand-sensed tactile acridity of EFY was determined by responses felt on the hand (Sahaand Hussain (1983); Paull et al., 1999). Hand sensed acridity in EFY as perceived by sensory panellists decreased significantly with increasing alkali concentration (Table 1). Soaking time had little effect on acridity. Tu (1981) used aqueous alkali to remove acrid principles from aroid corms and products prepared from them did not irritate mucous membranes in the mouth and throat. Similar effects were reported by Huang and Hollyer (1995), who used alkali for removing acridity from Araceae tubers.

Mouth feel acridity perceived in the EFY-milk mix was decreased as alkali increased. Soaking time did not affect acridity. The tactile acridity score of EFY paste obtained from NaCl treatment varied with salt concentration and soaking period (Table 2). With increasing salt and soaking duration, the tactile acridity score increased. Green and

Table1. Hand-sensed tactile acridity score and mouthfeel acridity in EFY-milk mix of the EFY corm pieces soaked in alkali solution

	NaOH(%) concentration	Soaking time (min) 60	90	120	Mean
Hand-sensed tactile acridity score*	0.00	1.0 ± 0.0	1.0 ± 0.0	1.1 ± 0.1	1.03[b]
	0.01	1.1 ± 0.1	0.7 ± 0.1	0.8 ± 0.2	0.83[b]
	0.05	0.6 ± 0.1	0.6 ± 0.0	0.5 ± 0.1	0.57[a]
	0.10	0.4 ± 0.1	0.5 ± 0.0	0.4 ± 0.1	0.45[a]
	Mean	0.78	0.69	0.7	
Mouthfeel acridity score**	0.00	7.14 ± 0.14	7.29 ± 0.14	7.07 ± 0.02	7.17[b]
	0.01	7.04 ± 0.10	7.00 ± 0.08	6.75 ± 0.08	6.93[ab]
	0.05	7.17 ± 0.15	7.00 ± 0.10	6.97 ± 0.18	7.05[ab]
	0.10	6.79 ± 0.06	6.61 ± 0.19	6.91 ± 0.11	6.77[a]
	Mean	7.04	6.98	6.93	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test; *measured on 5 point semi-structured scale (0- nil acridity, 4- extreme acridity); **measured on 9 point hedonic scale

Table 2. Hand-sensed tactile acridity score and mouth feel acridity in EFY-milk mix of the EFY corm pieces soaked in NaCl solution

	NaCl concentration (%)	Soaking time (min) 60	90	120	Mean
Hand-sensed tactile acridity score*	0	1.00 ± 0.00	1.00 ± 0.00	1.10 ± 0.10	1.05[a]
	2	1.15 ± 0.15	1.30 ± 0.10	1.50 ± 0.10	1.32[b]
	6	1.00 ± 0.20	1.20 ± 0.00	1.35 ± 0.05	1.18[ab]
	10	1.35 ± 0.05	1.95 ± 0.05	1.75 ± 0.05	1.68[c]
	Mean	1.13[A]	1.38[B]	1.43[B]	
Mouthfeel acridity score**	0	7.14 ± 0.14	7.29 ± 0.14	7.07 ± 0.02	7.17
	2	7.10 ± 0.23	6.75 ± 0.10	6.60 ± 0.32	6.82
	6	6.65 ± 0.18	6.80 ± 0.08	6.90 ± 0.20	6.78
	10	7.10 ± 0.20	6.68 ± 0.10	7.14 ± 0.02	6.97
	Mean	7.00	6.88	6.93	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test; *measured on 5 point semi-structured scale (0- nil acridity, 4- extreme acridity); **measured on 9 point hedonic scale

Gelhard (1989) reported NaCl produced sensations of irritation in the mouth. Salt increased a burning sensation produced by capsaicin in the mouth (Prescott and Allen, 1984). This phenomenon occurring in the oral cavity could arguably point towards some kind of complex synergistic interaction occurring between irritation perceived due to raphides (oxalates) and residual salt in the EFY paste which resulted in enhanced acridity. The mouth feel acridity of EFY-milk mix was not affected by soaking and cooking. The tactile acridity as evaluated by panellists indicated increased as salt concentration increased (Table3). The tactile acridity score of acidulated saline pre-soaked and cooked EFY paste was higher than plain water pre-soaked and cooked EFY paste. The mouth feel acridity score of the blend was affected by salt concentration as well as the interaction of salt concentration and soaking time. Although mouth feel acridity varied it did not change up to 6% salt concentration, but increased at 10% salt.

Alkali soaking was effective in alleviating the tactile acridity. There were no significant differences in oxalate content of EFY paste due to different soaking treatments. Alkaline treatment reduced tactile acridity whereas the other 2 combinations increased the tactile acridity. Reduction in tactile acridity due to alkali treatment was affected by concentration and soaking time. The

Table 3. Hand-sensed tactile acridity score and mouthfeel acridity in EFY-milk mix of the EFY corm pieces soaked in acidulated NaCl (pH- 3.5) solution

	NaCl Concentration (%)	Soaking time (min) 60	90	120	Mean
Hand-sensed tactile acridity score*	0	1.00 ± 0.00	1.05 ± 0.05	1.10 ± 0.10	1.05[a]
	2	1.45 ± 0.25	1.30 ± 0.20	1.25 ± 0.05	1.33[ab]
	6	1.10 ± 0.00	1.05 ± 0.05	1.05 ± 0.05	1.07[a]
	10	1.30 ± 0.10	1.35 ± 0.05	1.70 ± 0.20	1.45[b]
	Mean	1.21	1.19	1.28	
Mouthfeel acridity score**	0	7.14 ± 0.14	7.29 ± 0.14	7.07 ± 0.02	7.17[a]
	2	7.09 ± 0.19	6.78 ± 0.10	7.41 ± 0.13	7.09[a]
	6	7.22 ± 0.16	6.97 ± 0.15	6.97 ± 0.09	7.05[a]
	10	7.93 ± 0.16	7.69 ± 0.11	7.43 ± 0.13	7.68[b]
	Mean	7.35	7.18	7.22	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test; *measured on 5 point semi-structured scale (0- nil acridity, 4- extreme acridity); **measured on 9 point hedonic scale

reduction in acridity was mainly due to cooking implying that soaking in salt solution or soaking duration was not effective in reducing tactile acridity. Hang et al. (2013) reported reduction in oxalate content by soaking for 10 hours, much longer than used in this present study.

Color described with the Hunter L*, a* and b* values as per opponents color theory. The Hunter L* value, indicating whiteness (or blackness), of EFY paste varied (Table 4). Alkali treatment, soaking time and their interaction affected L* values. In general L* value decreased with increasing soaking time and increasing alkali. Longer soaking time and higher sodium hydroxide tended to make yam paste darker. However, at the lowest concentration of sodium hydroxide solution soaking time had an opposite effect and the mean L* value was higher than that for control (soak water only). The Hunter a* value, which signifies the redness/greenness, of the EFY paste was affected by alkali and soaking time (Table 4). For any duration of soaking, with increasing alkali, EFY paste became more red. For each alkali concentration with increasing soaking time the redness of EFY paste first decreased and then increased. Alkali affected Hunter b* value of cooked EFY paste (Table 4). With increased alkali level yellowness, Hunter b* component, decreased slightly and was similar to the plain – water soaked EFY on the yellowness scale (Table 4). The Hunter L, a and b parameters can be integrated into a single value Whiteness Index (WI), expressed as color or whiteness of a product. The WI, which measures discoloration of the product, decreased with increasing alkali (Table 4), apparently due to development of browning intermediates.

Soaking in sodium chloride solution was expected to inactivate acrid components in EFY. The Hunter L* value of EFY paste was affected by salt concentration (Table 5). It increased with increasing salt concentration up to 6% but then declined at 8%; there was an interaction effect between salt concentration and soaking duration. Soaking time did not affect the L* value. As, sodium chloride is an effective browning inhibitor (Pilizora and Subaric, 1998) inhibiting the polyphenoloxidases (PPO), the browning is concentration dependent. Pizzocaro et al. (1993) reported 0.02-0.1% salt concentration to be activating for PPOs. Taufel and Voigt (1964) reported that 0.5-1.0% salt concentration inhibited browning. The increase in the L* value up to 6% salt concentration may be attributed to reduced polyphenoloxidase activity. The decrease in L* value using 2 or 10% saline soaking possibly indicates some kind of complex mechanism inducing color change instead of just PPO inhibition. Salt concentration affected Hunter a* value of the cooked-EFY paste derived after NaCl pre-soaking (Table 5). The L* and a* value at 6% salt concentration was the lowest suggesting a decrease in redness and increase in greenness. At 10% NaCl concentration the a* value was

Table 4. Hunter colour parameters of the EFY soaked in NaOH solution

NaOH Concentration (%)	Soaking time (min) 60	90	120	Mean
	Hunter L* value			
0.00	50.34 ± 0.78	50.29 ± 0.12	50.39 ± 0.34	50.34[b]
0.01	51.64 ± 0.27	52.83 ± 0.17	53.20 ± 0.45	52.55[c]
0.05	50.85 ± 1.09	50.73 ± 0.19	49.61 ± 0.40	50.40[b]
0.10	48.17 ± 0.55	46.25 ± 0.59	43.67 ± 0.55	46.03[a]
Mean	50.25[A]	50.02[AB]	49.22[BC]	
	Hunter a* value			
0.00	9.95 ± 0.19	9.81 ± 0.16	10.66 ± 0.24	10.14[a]
0.01	10.30 ± 0.10	8.70 ± 0.00	8.89 ± 0.14	9.30[a]
0.05	10.35 ± 0.79	9.29 ± 0.46	10.28 ± 0.18	9.97[a]
0.10	11.42 ± 0.14	11.32 ± 0.34	11.85 ± 0.84	11.53[b]
Mean	10.51	9.78	10.42	
	Hunter b* value			
0.00	24.46 ± 0.34	24.40 ± 0.28	24.45 ± 0.45	24.44[b]
0.01	24.98 ± 0.44	26.05 ± 0.91	24.41 ± 0.59	25.15[b]
0.05	25.03 ± 0.85	25.75 ± 0.89	24.25 ± 0.24	25.01[b]
0.10	23.31 ± 0.69	23.02 ± 0.29	22.16 ± 0.42	22.83[a]
Mean	24.45	24.80	23.82	
	Whiteness index			
0.00	43.76 ± 0.87	43.76 ± 0.26	43.67 ± 0.06	43.73[b]
0.01	44.60 ± 0.42	45.42 ± 0.58	46.47 ± 0.15	45.49[c]
0.05	43.88 ± 0.73	43.64 ± 0.65	43.14 ± 0.49	43.55[b]
0.10	42.03 ± 0.24	40.44 ± 0.48	38.32 ± 0.51	40.26[a]
Mean	43.56	43.31	42.90	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

similar to the control, indicating an interaction between concentration and soaking time. The Hunter b* value of the cooked NaCl treated EFY paste was altered by NaCl concentration and like L* value increased to a maximum in 6% salt soaked tissue, but declined at 10% salt solution. Variability in whiteness index was similar to Hunter L* value. The Hunter color parameters attained either a maximum (L*, b* and WI) or a minimum (a*) in EFY soaked in 6% NaCl solution. The cause of change could be related to activity of polyphenol as enzymes from EFY or other change that might be occurring during the cooking process.

Hunter L* value of acidulated salt-water soaked and plain-water cooked, EFY paste was affected by process variables and their interaction (Table 6). The 2% NaCl soak resulted in increased L* with a small, but significant, decrease for higher NaCl concentrations at the soaking pH remaining constant at 3.5. When soaking time was increased from 60 to 90 min, the L* value increased but soaking for 120 min resulted in lower values. EFY paste from acidulated NaCl soaked EFY corm was generally lighter in color than water soaked and cooked EFY. A lower pH hampers polyphenolase activity (McCord and Kilara, 1983), which is associated with enzymatic reactions causing browning. Phenolase enzymes are inactivated due to copper-chelating action of citric acid (Jiang et al., 1999). Citric acid has been employed alone, or with other chemicals, to retard browning in vegetables (Tortoe et al., 2007). The Hunter a* value (redness/ greenness) of acidulated saline soaked and cooked, EFY

Table 5. Hunter colour parameters of the EFY soaked in NaCl solution

NaCl Concentration (%)	Soaking time (min) 60	90	120	Mean
	HunterL* value			
0	50.34 ± 0.78	50.29 ± 0.12	50.39 ± 0.34	50.34[a]
2	49.90 ± 0.29	51.30 ± 0.44	51.54 ± 0.57	50.91[ab]
6	51.54 ± 0.77	53.66 ± 0.68	51.69 ± 0.73	52.30[b]
10	51.94 ± 0.96	49.81 ± 0.30	48.60 ± 0.51	50.12[a]
Mean	50.93	51.27	50.56	
	Hunter a*value			
0	9.95 ± 0.19	9.81 ± 0.16	10.66 ± 0.24	10.14[c]
2	9.95 ± 0.06	9.64 ± 0.24	8.95 ± 0.09	9.51[b]
6	8.95 ± 0.56	8.39 ± 0.07	8.73 ± 0.31	8.68[a]
10	8.95 ± 0.32	10.96 ± 0.16	10.36 ± 0.24	10.09[bc]
Mean	9.45	9.70	9.68	
	Hunter b*value			
0	24.46 ± 0.34	24.40 ± 0.28	24.45 ± 0.45	24.44[a]
2	24.75 ± 0.07	24.81 ± 0.69	26.13 ± 0.21	25.23[ab]
6	26.13 ± 0.68	26.81 ± 0.31	26.38 ± 1.20	26.44[ab]
10	26.16 ± 0.46	25.58 ± 0.43	25.36 ± 0.12	25.70[b]
Mean	25.37	25.40	25.58	
	Whiteness index			
0	43.76 ± 0.87	43.76 ± 0.26	43.67 ± 0.06	43.73[ab]
2	43.24 ± 0.22	44.50 ± 0.04	44.22 ± 0.61	43.99[ab]
6	44.22 ± 0.90	45.81 ± 0.72	44.25 ± 0.11	44.76[b]
10	44.55 ± 1.10	42.61 ± 0.04	41.76 ± 0.54	42.97[a]
Mean	43.94	44.17	43.47	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

paste varied. The Hunter a* value decreased with increasing NaCl concentration in acidulated saline. The decline in Hunter a* value indicates a decrease in formation of browning intermediates in acidulated NaCl treatment presumably due to conjugative effect of sodium chloride and citric acid in lowering the browning reactions (Rouet-Meyer and Phillipon, 1986). The Hunter a* value was not affected by increasing pre-soaking time. Hunter b* value of salt treated and cooked EFY paste varied. It was affected by salt concentration of the acidulated saline. An increase in yellowness of acidulated saline treated EFY paste was observed relative to plain-water soaking. Whiteness index was affected by salt concentration in acidulated saltwater and the trend was similar to the L* value. The yam paste was lighter when soaked in acidulated saline and cooked, compared to plain-water soaked and cooked yam. As subtle decrease occurred in whiteness with increasing salt concentration.

Conclusion

Oxalic acid is a normal product of human metabolism but intake of dietary oxalate may cause serious renal problems (Noonan and Savage, 1995). Soaking in salt solutions and cooking process are known to reduce the oxalate level of food stuffs primarily by leaching and hydro-thermal degradation. However, in the present study soaking treatments up to 120 min did not reduce the oxalate content but when combined with cooking, reduced oxalate content significanlty. Increased soaking may reduce acridity. Proper cooking of products

Table 6. Hunter colour parameters of EFY soaked in acidulated NaCl solution (pH - 3.5)

Salt Concentration (%)	Pre-soaking time (min) 60	90	120	Mean
		HunterL*value		
0	50.34 ± 0.78	50.29 ± 0.12	50.39 ± 0.34	50.34^{a}
2	54.36 ± 0.38	55.71 ± 0.61	54.56 ± 0.05	54.88^{c}
6	53.22 ± 0.30	53.38 ± 0.42	53.30 ± 0.11	53.30^{b}
10	54.02 ± 0.59	53.93 ± 0.10	51.63 ± 0.34	53.10^{b}
Mean	52.99^{AB}	53.33^{B}	52.40^{A}	
		Hunter a* value		
0	9.95 ± 0.19	9.81 ± 0.16	10.66 ± 0.24	10.14^{c}
2	7.41 ± 0.30	7.35 ± 0.06	7.03 ± 0.12	7.26^{b}
6	7.64 ± 0.16	7.11 ± 0.13	6.63 ± 0.18	7.13^{ab}
10	6.43 ± 0.06	6.98 ± 0.14	6.77 ± 0.14	6.73^{a}
Mean	7.86	7.81	7.77	
		Hunter b* value		
0	24.46 ± 0.34	24.40 ± 0.28	24.45 ± 0.45	24.44^{a}
2	26.96 ± 0.13	27.44 ± 0.03	27.41 ± 0.04	27.27^{c}
6	25.94 ± 0.21	25.50 ± 0.27	25.70 ± 0.32	25.71^{b}
10	27.97 ± 0.16	27.51 ± 0.22	26.47 ± 0.46	27.32^{c}
Mean	26.83	26.21	26.01	
		Whiteness index		
0	43.76 ± 0.87	43.76 ± 0.26	43.67 ± 0.06	43.73^{a}
2	46.48 ± 0.30	47.38 ± 0.51	46.47 ± 0.07	46.77^{c}
6	45.97 ± 0.15	46.39 ± 0.51	46.29 ± 0.27	46.21^{bc}
10	45.80 ± 0.59	45.89 ± 0.01	44.19 ± 0.50	45.29^{b}
Mean	45.50	45.86	45.15	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

containing oxalates is necessary before consumption to reduce oxalate content.

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