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Evaluation of yacon (*Smallanthus sonchifolius*) extracts as a potential antioxidant source in emulsion-type sausage during refrigerated storage

Kim, Y. J. [1] and Choi, I. H.[2]*

[1]Division of Life Resources, Daegu University, Gyong San, 712-714, South Korea.
[2]Department of Companion Animal and Animal Resources Sciences, Joongbu University, Geumsan-gun 312-702, South Korea.

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Yacon (*Smallanthus sonchifolius*) is a plant that grows in the Andean highlands of South America. Recent studies have shown that yacon is effective in improving antioxidant activity. In this study, the effects of different forms of yacon extracts (20% yacon water extract, 20% yacon juice, and 20% yacon extract) on the lipid oxidation and color of emulsion-type sausage were evaluated. Significant decrease in pH and residual nitrite (RN) values were observed as well as increased thiobarbituric acid reactive substances (TBARS) in all treatments over time. However, during the 30 days of storage, no differences were seen in pH values in any treatment. For color, differences in L*, a*, and b* due to each yacon extract were small, except at 0 days of storage. In conclusion, the addition of 20% yacon extract to emulsion-type sausages was most effective in improving lipid oxidative stability, which could lower pH.

Key words: Yacon water extract, yacon juice, yacon extract, lipid oxidation, color, emulsion-type sausage.

INTRODUCTION

Yacon (*Smallanthus sonchifolius*) is an herbaceous plant that grows in the Andean highlands of South America (Grau and Rea, 1997; Castro et al., 2012; Saldaña et al., 2014). It has been used as food and medicine because of its juicy tuberous root and medicinal properties (Park and Han, 2013). The tuberous roots produced by this plant are similar to sweet potatoes in appearance, but they have a relatively low energy value despite the sweet taste and crunchy flesh (Aybar et al., 2001; Lachman et al., 2003). In terms of nutritional and medicinal properties, yacon has abundant fructans with low glucose, which is potentially beneficial in the control of diabetes (Yan et al., 1999). Studies have shown that yacon tuber extracts have a hypoglycemic effect in individuals with diabetes and in weight reduction (Aybar et al., 2001; Lachman et al., 2003). Tubers are generally used as a source of natural sweetener

*Corresponding author. E-mail: ihchoi@joongbu.ac.kr. Tel: +82-19-527-7422. Fax: +82-41-750-6179.

Abbreviation: TBARS, Thiobarbituric acid reactive substances; **RN**, residual nitrite.

for individuals with renal disorders and digestive problems (Park and Han, 2013). Yacon leaves are used either fresh or dried as a tea, which has anti-diabetic properties (Simonovska et al., 2003). For example, in Brazil, the dried leaves were used as the medicinal ingredient to make yacon tea and said to be antidiabetics (Aybar et al., 2001). The study conducted by Volpato et al. (1997) using yacon leaves showed lowering blood glucose. The tuberous roots, leaves, and stems of yacon contain up to 80% water, 0.3-21.18% proteins, 0.28-26.85% fiber, minerals such as Ca, K, and Mg (Lachman et al., 2003), as well as polyphenol compounds (up to 3.8% dry weight), which exhibit antioxidant activity (Castro et al., 2012).

In general, natural antioxidants, which occur innately in plants, may help to counter the detrimental effects of reactive oxygen species (ROS) and free radicals that cause lipid oxidation via phenolic compounds. The main characteristic of antioxidants such as phenolic acids and polyphenols is their ability to trap free radicals and inhibit oxidative mechanisms (Borkataky et al., 2013). It was previously demonstrated that the major antioxidant compounds in yacon roots are chlorogenic acid and tryptophan (Castro et al., 2012). Takenaka et al. (2003) also reported that caffeic acid derivatives in yacon root belonged to five groups: chlorogenic acid, 3,5-dicaffeoylquinic acid, 2,4- or 3,5-dicaffeoylatraric acid, 2,5-dicaffeoylatraric acid, and 2,3,5- or 2,4,5-tricaffeo- ylatraric acid.

At present, the antioxidant properties in yacon have been studied in detail, but there are no studies on the effect of different forms of yacon extracts on antioxidants and color of meat and meat products. Hence, the objective of this study was to evaluate the effectiveness of different forms of yacon extracts on thiobarbituric acid reactive substances (TBARS), residual nitrite (RN), and color changes in emulsion-type sausage during refrigerated storage.

MATERIALS AND METHODS

Preparation of yacon extract

Yacon roots used in this study were purchased from a local market (Munkyong, South Korea). To prepare yacon water extracts, 500 g of yacon roots was weighed and extracted with 1,000 ml distilled water using steam distillation at 70°C for 5 h. For yacon juices, approximately 500 g of yacon roots was washed and squeezed using a juicer (KJ-303; Kwang Jin Co.; South Korea). Yacon extracts were prepared using the following procedure: 500 g of yacon roots was mixed with 1, 000 ml of 70% ethanol for 30 min, extracted by steam distillation at 70°C for 5 h, and then cooled to room temperature.

Sausage preparations

Emulsion-type sausages were prepared using fresh boneless pork trimmed of excessive fat and connective tissue, and ground through a 5 mm plate. The emulsion type sausages formulation consisted of four treatments [a no-additive control, 20% yacon water extract (T1), 20% yacon juice (T2), or 20% yacon extract (T3)]. The amount of the ingredients, expressed per 10 kg of sausage, are as follows: 55% ground pork meat, 15% fat, 5.3% cornstarch, 3% sausage seasoning (containing 0.4% nitrite), 1.5% salt, 0.2% polyphosphate, and 20% iced water. The control was 2, 000 ml ice water (20% ice water) as 20% for a 10 kg sausage. For preparation of 20% yacon water extract 20% yacon juice, and 20% yacon extract, the extract was added to ice water until the volume was adjusted to 2, 000 ml and mixed together. All treatments were then added to the ground meat, mixed, and homogenized in a chopper to obtain finer meat particles for greater protein extraction. Fat was also added to the formulation after proteins were solubilized. After mixing in an emulsifier (Kenmix Electronic, model FP800; Kenwood Ltd.; New Hampshire, UK) for 5 min, the batter was stuffed into polyvinylidene chloride casings (50 mm diameter; Viskase Corporation; Chicago, IL). During the emulsification process, ice water was added to absorb the generated heat. Samples were cooked for 70 min in a cooking chamber (NU-VUES-3; Food Service System; USA) until the temperature reached 75°C. All samples were cooled in ice water for 2 h, stored at 4°C, and analyzed after 0, 10, 20, and 30 days of storage. All parameters were determined in triplicate.

pH

The pH was determined according to the method of AOAC (1990). Approximately 10 g of sausage was added to 90 ml of distilled water and homogenized using a blender. pH was measured using a digital pH meter (Model 520A; Orion, USA).

Thiobarbituric acid reactive substance (TBARS)

The TBARS assay was determined according to a previous study (Witte et al., 1970). Approximately 20 g of sample was weighed and homogenized in 50 ml of 20% trichloroacetic acid solution (in 2 M phosphate solution) using a blender. The sausage homogenate was then blended with 50 ml of distilled water. Samples were filtered through No. 1 filter paper, and 5 ml of the filtered solution in a test tube was blended with 5 ml TBA solution (0.005 M in water). Tubes were kept in the dark at room temperature for 15 min before use. Absorbance of the supernatant was determined at 532 nm using an ultraviolet/visible (UV/VIS) spectrophotometer (UV-24D; Shimadzu; Tokyo, Japan). The amount of TBARS was expressed as mg malondialdehyde (MDA) per kg sausage.

Residual nitrite (RN)

RN was determined according to AOAC methods (1990). Approximately 5 g of sausage was mixed with 50 ml of distilled water for 2 min, heated for 10 min at 40°C in a boiling water bath, and then mixed with 5 ml of saturated HgCl solution. Mixtures were then heated again in a boiling water bath at 80°C for 2 h. After cooling to room temperature, the supernatant was added to 1 ml of sulfamilamide and stored at room temperature for 15 min. The absorbance of this solution was measured in an UV-VIS spectrophotometer (UV-24D) at 540 nm and RN values were expressed as mg per kg of sausage.

Color analysis

Determination of sausage sample color was performed with a Minolta Chromameter (Minolta CR-300; Tokyo, Japan) calibrated using a white standard plate. Values for the white standard tile were as follows: lightness, L* = 96.16; redness, a* = 0.10; and yellowness, b* = 1.90. Measurements were taken at five randomly selected locations on each sample.

Table 1. Effect of different forms of yacon (*Smallanthus sonchifolius*) extracts on pH, TBARS, and RN in emulsified sausage during storage at 4°C.

Parameter	Treatments	Storage time (days)			
		0	10	20	30
pH	Control	6.60±0.05^{aA}	6.45±0.03^{bA}	6.28±0.08^{cAB}	6.29±0.11^{cA}
	T1	6.64±0.02^{aA}	6.44±0.04^{bA}	6.37±0.02^{bA}	6.28±0.09^{cA}
	T2	6.44±0.04^{aB}	6.34±0.06^{bB}	6.23±0.05^{cB}	6.15±0.05^{cA}
	T3	6.43±0.06^{aB}	6.26±0.06^{bB}	6.22±0.05^{bcB}	6.13±0.07^{cA}
TBAR (mg MDA/kg)	Control	0.30±0.02^{dA}	0.39±0.01^{cA}	0.45±0.03^{bA}	0.50±0.01^{aA}
	T1	0.27±0.02^{dAB}	0.32±0.03^{cB}	0.37±0.03^{bBC}	0.46±0.02^{aB}
	T2	0.25±0.02^{bB}	0.29±0.05^{bB}	0.40±0.01^{aB}	0.44±0.02^{aB}
	T3	0.23±0.02^{cC}	0.29±0.03^{bB}	0.34±0.03^{aC}	0.38±0.03^{aC}
RN (mg/kg)	Control	7.41±0.13^{aA}	7.19±0.07^{bA}	5.77±0.10^{cA}	5.24±0.12^{dA}
	T1	7.03±0.09^{aB}	6.83±0.11^{bB}	4.92±0.06^{cB}	4.26±0.11^{dB}
	T2	6.58±0.22^{aC}	5.97±0.10^{bC}	4.79±0.17^{cB}	4.16±0.08^{dB}
	T3	5.94±0.07^{aD}	5.57±0.10^{bD}	4.29±0.08^{cC}	3.91±0.19^{dC}

$^{a-d}$Means within row with different superscripts are significantly different (p<0.05); $^{A-D}$Means within columns with different superscripts are significantly different (p<0.05); [1]Control, no yacon; T1: 20% yacon water extract; T2: 20% yacon juice; T3: 20% yacon extract.

Statistical analysis

All data were subjected to an analysis of variance (ANOVA) using the General Linear Model (GLM) of the SAS procedure (SAS, 2002). Differences among treatment means were determined using Duncan's multiple range tests, and significance was defined at the 5% level (Duncan, 1955).

RESULTS AND DISCUSSION

The effects of addition of different forms of yacon extracts on pH, TBARS, and RN contents during storage are presented in Table 1. Overall, there were significant differences (p<0.05) in pH, TBARS, and RN values among emulsion-type sausages with different forms of yacon extracts over time. However, during 30 days of storage, no differences (p>0.05) were observed in pH values in any treatment. As storage days increased, all treatments showed reduced pH levels, indicating that the number of storage days significantly affected pH levels. Sausages with addition of different forms of yacon extracts showed lower pH values compared to controls, due to the presence of antioxidant. Treatment with 20% yacon juice (T2) and 20% yacon extract (T3) resulted in lower pH values than other treatments over time. Similar findings were also observed by Kim et al. (2010), who found that different forms of garlic decreased pH in emulsion-type sausages during storage, with pH values ranging from 5.19 to 6.38. According to Aksu (2007), pH values play an important role in antioxidant effectiveness when antioxidants are added to meat and meat products. In the current study, a reduction in TBARS values was observed after treatment with different forms of yacon extracts in emulsion-type sausages over time compared to the control. In addition, all treatments tended to increase TBARS values over increasing storage days.

Among the antioxidants tested, 20% yacon extract (T3) resulted in the most significant reduction in TBARS, while 20% yacon water extract (T1) was the least effective in reducing lipid oxidation in emulsion-type sausage. This finding agreed with Rababah et al. (2011), who reported that addition of plant extracts to goat meat decreased TBARS values concomitant with increased storage days. In general, antioxidants are compounds that retard autoxidation by interrupting free radical chain reactions such as lipid peroxidation (Nawar, 1996). Thus, the mechanism by which different forms of yacon extracts reduce lipid oxidation could be related to either inhibition of free radical formation or interruption of the chelation of free ions released from hemoproteins (Shahidi, 2000). Overall RN values in all sausages decreased as storage days increased, and RN values in sausages with three different forms of yacon extracts (T1, T2, and T3) were lower compared to controls. The inhibiting effect on RN values in emulsion-type sausage was highest with 20% yacon extract (T3), followed by 20% yacon juice (T2), and then 20% yacon water extract (T1) during 30 days of storage. The reduced RN values may be due to decreased pH and antioxidant effects. These results are in agreement with results reported by Kim et al. (2002), who demonstrated that the nitrite-scavenging effect (NSE) was dependent on the pH and increased with the concentration of garlic extract. Nitrite has been extensively used for color and flavor development; however, the use of nitrates has been reduced

Table 2. Effect of different forms of yacon (*Smallanthus sonchifolius*) extracts on color in emulsified sausage during storage at 4°C.

Parameter	Treatments	Storage time (days)			
		0	10	20	30
L* (lightness)	Control	67.96±0.14^{aA}	67.10±0.30^{bA}	65.66±0.33^{cA}	64.38±0.14^{dA}
	T1	68.19±0.18^{aA}	65.73±0.44^{bB}	64.70±0.48^{cB}	63.81±0.20^{dBC}
	T2	68.09±0.27^{aA}	65.56±0.17^{bB}	64.03±0.42^{cB}	63.94±0.07^{cB}
	T3	67.81±0.56^{aA}	65.27±0.07^{bB}	63.99±0.22^{cB}	63.51±0.22^{dC}
a* (redness)	Control	8.16±0.11^{bA}	8.30±0.04^{abB}	8.46±0.10^{aB}	8.48±0.17^{aB}
	T1	8.09±0.06^{cA}	8.32±0.06^{bAB}	8.50±0.09^{aB}	8.57±0.13^{aAB}
	T2	8.16±0.09^{cA}	8.41±0.09^{bAB}	8.79±0.09^{aA}	8.81±0.14^{aA}
	T3	8.18±0.03^{cA}	8.46±0.11^{bA}	8.78±0.11^{aA}	8.79±0.12^{aA}
b* (yellowness)	Control	7.99±0.09^{aA}	7.70±0.18^{abB}	7.46±0.26^{bB}	7.56±0.09^{bB}
	T1	8.07±0.02^{aA}	7.73±0.13^{bB}	7.78±0.16^{bAB}	7.73±0.14^{bAB}
	T2	7.99±0.11^{aA}	7.98±0.06^{aAB}	7.57±0.24^{bB}	7.63±0.11^{bB}
	T3	8.11±0.07^{aA}	8.00±0.30^{abA}	8.01±0.03^{abA}	7.91±0.07^{bA}

$^{a-d}$Means within row with different superscripts are significantly different (p<0.05); $^{A-C}$Means within columns with different superscripts are significantly different (p<0.05); Control, no yacon; T1, 20% yacon water extract; T2, 20% yacon juice; T3, 20% yacon extract.

because of their toxic properties (European Union, 2006). In view of the growing consumer demand for food with natural additives (for example, yacon extracts), RN reduction associated with decreased pH is desirable.

Analysis of the color of emulsion-type sausages with three forms of yacon extracts at different storage days is shown in Table 2. At 0 days of storage, treatments were not significantly different (p> 0.05) based on L*, a*, and b* values. Overall changes in color of emulsion-type sausages showed increased a* values and decreased L* and b* values in all treatments as the storage length increased, but differences in L*, a*, and b* values of emulsion-type sausages induced by the three different forms of yacon extracts were small, indicating that yacon extracts were less effective in improving color stability of emulsion-type sausages. However, Rohlík et al. (2010) observed a positive effect of antioxidants (rosemary extract) on color stability and elimination of color varieties in different parts of dried sausages.

Conclusions

The findings of this study suggested that adding different forms of yacon extracts to emulsion-type sausages decreased pH, TBARS (lipid oxidation) and RN values when compared with the controls over time. Among antioxidant used in this study, 20% yacon extract caused the most significant reduction in lipid oxidation and RN of emulsion-type sausages. However, inclusion of different forms of yacon extracts was less effective in improving color stability of emulsion-type sausages. In order to fully understand the effectiveness of yacon extracts, further research on organoleptic properties, color stability, and sensory evaluation during refrigerated storage should be done.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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