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Development of a non-commercial sugar-free barbecue sauce

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Abstract

There has always been a challenge in manufacturing a sugar free sauce. A basic barbecue sauce formulation was used to make 5 sugar-free preparations combining selected levels of xanthan gum, modified waxy maize starch, sucralose, and acesulfame-K. Physical, chemical, microbial and sensory properties were used to evaluate the product quality. Total Aerobic Plate Count was below detectable limits before and after the incubation period for all 6 products. Total Soluble Solids, water activity and pH −before and after incubation− of the control were significantly different from all 5 sugar-free treatments. Descriptive sensory analysis of prepared products showed that SU treatment (2.0% Starch+ 0.3% Sucralose) exhibited the best in all the sensory properties that were determined compared to all other treatments. One sugar free preparation was significantly more viscous than the control. This study will help producers in formulating a new a sugar free healthy barbecue sauce with properties closely comparable to a sugar containing control formula.

Key words: Sugar free, Barbecue Sauce, Quality Evaluation

Introduction

Barbecue sauce was not invented in America and its origins are not known. In the United-States, barbecue -or BBQ- originated in the late 1800's during Western cattle drives. The cowboys were fed a tough and stringy piece of meat that required five to seven hours of cooking to tenderize; marinades or sauces were often added to the meat to improve flavor. Today, there are four major types of barbecue sauce: Kansas City, North Carolina, Memphis, and Texas-style (Raichlen, 1998). They differ in terms of thickness and taste that goes best with the type and/or cut of meat. These barbecue sauces are sweet and contain a significant amount of sugars in the form of high fructose corn syrup, sugar, honey, molasses, etc. Some brand name barbecue sauces contain up to 50% sugar in their formulations. The calories contributed by these sugars do not mitigate some of the biggest health problems in the United States: obesity and diabetes. According to the American Diabetes Association, 18.2 million people in the United States have diabetes, and 5.2 million of them don't know it (ADA, 2005). Also, Type 2 diabetes and its associated long term complications can cost developed nations up to 10% of its financial budget, as well as decreasing quality of life and length of life by up to ten years (Khunti, 2012). In addition, 65% of Americans are overweight and 31% are obese (Flegal et al., 2002). The economic burden of diabetes and obesity in the United States is enormous. Direct and indirect medical expenditures attributable to diabetes in 1997 were estimated at $98 billion. Medical expenditures incurred by people with diabetes were $10,071 per capita, compared with $2,669 for non-diabetics (ADA, 2005). The total cost attributable to obesity was $99.2 billion (Wolf & Colditz, 1998). In a new study, it was found that in the USA the annual cost for the normal weight person was US$ 2578, overweight person was US$2262 while the obese person was $3042 (John et al., 2012). Providing obese and/or diabetic individuals with sugar free/low calorie products containing alternative sweeteners may alleviate these serious health issues. Gamonpilas et al. (2011) showed the

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possibility of producing a chili sauce by using xanthan-starch mixture to improve the rheological properties of the product. Also, Krystyjan et al. (2012) produced caramel sauces thickened with combinations of potato starch and xanthan gum. In their study, it was found that the treatment thickened with 0.3% potato starch and 0.02% xanthan gum, received the highest sensory score. There has always been a challenge in manufacturing a sugar free product that is comparable to its original formulation in terms of flavor, texture and shelf-stability. Today, new artificial sweeteners provide sweetness without the extra calories of natural sweeteners and without altering blood glucose levels. They do not count as a carbohydrate, fat, or any other exchange. They are excellent solutions for dieters, diabetics, or simply for new product development and line extensions. Five nonnutritive sweeteners with intense sweetening power have FDA approval (acesulfame-K, aspartame, neotame, saccharin, sucralose) and estimated intakes below the Acceptable Daily Intake. Nonnutritive sweeteners may assist in weight management, control of blood glucose, and prevention of dental caries. Over the years, the effects of nonnutritive sweetener use on health have been a concern among health professionals. FDA approved nonnutritive sweeteners are safe for human consumption, and are mainly used for children and pregnant women if taken in its permitted level. These permitted levels are: for Acesulfame-K is up to 15 mg/kg bw/day, and for Sucralose is up to 1.6 mg/kg bw/day (ADA, 2004). The focus of this research was to formulate a sugar free barbecue sauce with properties closely comparable to a sugar containing control formula.

Materials and Methods

Preliminary Work

Extensive preliminary work was conducted on basic barbecue sauce recipes, substituting brown sugar with different levels of the alternative sweeteners and/or thickening agents to determine their most suitable levels for the purpose of this research. Usage levels for xanthan gum and the modified food starch were determined according to recommendations from suppliers and after reviewing relevant research papers (Sanderson, 1996; Seib, 1998). Usage levels of the artificial sweeteners were originally determined according to their relative sweetness intensity as compared to sucrose: sucralose 600 times sweeter than sucrose and acesulfame-K, 200 times sweeter than sucrose (Aramouni et al., 1998). Substitution of the brown sugar resulted in color differences and proper adjustment was made using an artificial brown color. In addition to adequate usage levels, preliminary work proved that usage of tomato sauce Kroger's Brand (local Grocery Store) - rather than tomato paste– as a base resulted in a uniform product and substantially reduced syneresis.

Barbecue Sauce Ingredients and Preparation

The ingredients used in all barbecue sauce formulations were Xanthan gum: Colloides Naturals, Inc., (Bridgewater, NJ); Modified Food Starch: Cerestar USA(Hammond, IN); Acesulfame Potassium: American International Foods, Inc (Grand Rapids, MI); Sucralose: McNeil Specialty Products Co. (New Brunswick, NJ); Brown Sugar : Kroger's Brand (local Grocery Store); Artificial Color: Chr. Hansen, Inc., (Milwaukee, WI); tomato sauce: Kroger's Brand (local Grocery Store); vinegar: Kroger's Brand (local Grocery Store); onion powder, garlic powder: Kroger's Brand (local Grocery Store); salt: Kroger's Brand (local Grocery Store). Five treatments of sugar free barbecue sauce and a control were formulated (Table 1).

Table 1. Composition* of five different treatments of sugar free barbecue sauce and control (% by weight).

Treatment	Xanthan gum	Modified Food Starch	Acesulfame Potassium	Sucralose	Brown sugar	Artificial Color
XKSU	0.1	1.0	0.15	0.05	-	0.15
SK	-	1.50	0.25	0.15	-	0.15
XU	0.25	-	-	-	-	0.15
SU	-	2.0	-	0.30	-	0.15
XK	0.125	-	0.5	-	-	0.15
Control	-	-	-	-	32	-

* Common ingredients used were tomato sauce (2.8 Kg), vinegar (560 mL), onion powder (50 g), garlic powder (50 g), and salt (50 g). XKSU (0.1% Xanthan+1.0% Starch+0.15% Acesulfame-K+0.05% Sucralose), SK (1.5% Starch+0.25% Acesulfame-K), XU (0.25% Xanthan+0.15% Sucralose), SU (2.0% Starch+ 0.3% Sucralose), XK (0.125% Xanthan+ 0.5% Acesulfame-K), CONTROL (32% Sugar).

Barbecue sauce chemical and physical evaluation

Moisture content and water activity

The moisture content of the sauce was measured using AACC approved method 44-15A (AACC, 1995) and water activity (AOAC, 1980) was determined using an AQUA LAB CX-2 (Decagon CO.,Pullman,WA). A conventional oven (Fisher Scientific Isotope incubator, Pittsburgh, PA) was used.

pH Measurements and total soluble solids

The pH of the sauce was measured with a pH meter (Accumet portable AP63, Fisher Scientific, Denver, CO) with automatic temperature compensation, the Electrometric Method, AACC method 02–052 (AACC, 1995). The pH meter was calibrated with buffer solutions of 4 and 7. All measurements were recorded at ambient temperature when the readings were stable. Total soluble solids were determined by using a refractometer (Abb, Carnation, Washington).

Barbecue sauce physical evaluation

Color

A Hunterlab Ultrascan Sphere Spectrocolorimeter (Hunter Associates Laboratory Inc., Reston, Virginia) was used for color measurements. Fifty grams of the sauce were placed on a small white paper plate, the Spectrocolorimeter placed at approximately 1 cm from the surface of the product which was scanned to determine the L, a, and b values using illuminant C (at a 10° angle) which is equivalent to normal daylight.

Rheology

A steady shear test of the six different treatments of barbecue sauce was performed using a Bohlin VOR rheometer (Bohlin Reologi B, Lund, Sweden). Rheological testing was conducted using concentric cylinder geometry with a torque element of 91.1 g. The apparent viscosity was calculated within shear rates ranging from 0.92 s^{-1} to 91.9 s^{-1} at 23°C (storage temperature)

Barbecue sauce microbial evaluation

Microbiological tests were performed using 3M Petrifilm™ Plates (3M Microbiology Products, St. Paul, MN) for yeast and mold count and total aerobic plate counts. The total aerobic plate counts plates were held in an incubator (Boekel Industries Inc, Feasterville, PA) at 35°C and the yeast and mold plates were held at 20°C for 48 hours before evaluation.

Descriptive sensory analysis

The tested barbecue sauces were basic non-commercial formulations hence a complete descriptive profile was not needed. Product attributes were pre-determined by the author for their relevance and comparative value. A five-member panel was comprised of students and faculty members, who had previously served as descriptive panels. The panelists spent 6 hours (divided in 3 sessions) of training −conducted by the author−- to become familiar with the definitions and references for the following attributes: color, thickness, sweet, sour, bitter aftertaste, and metallic aftertaste. Testing of the samples was done in 2 one-hour sessions. The panel evaluated the samples and reached consensus for each attribute. Attributes of the samples were identified and the intensities were quantified, utilizing a 15 point scale with 0.5 increments (0.0 = none; 0.5 – 5.0 = slight; 5.5 – 10.0 = moderate; 10.5 – 15.0 = extreme). Samples were presented monadically and coded with random 3-digit numbers. Three replications of each sample were evaluated.

Nutrition labeling

Nutrition analysis was performed using the Genesis R&D labeling program (ESHA Research, Salem, OR). Moisture content was adjusted for moisture loss during the processing of samples.

Statistical analysis

This research used a randomized complete block (RCB) design with 3 replications. Data were analyzed for significant differences by examining the appropriate least significant difference (LSD) values.

Results and Discussion

Moisture content and water activity

The moisture content value was calculated to adjust for the moisture loss during processing to accurately produce the nutrition label. The average of a total of 9 calculations (3 replications * 3 measurements) was 5%± 0.05. There were no differences in water activity (A_w) among the sugar-free treatments (Table 2). However, the control formula had a significantly lower A_w (0.951) than all the other treatments due to the water binding ability of the sugar present in the control. This difference in water activity could make the sugar free preparations more susceptible to mold and yeast growth.

The water activity of the barbecue sauce makes bacterial growth possible for all formulations. However, their low pH was reported to be a limiting factor (Jay, 1992). Sauces are typically shelf stable, implying a shelf-life of several months at room temperature. This can be achieved by (i) a low pH, due to the presence of organic and inorganic acid or (ii) a salt concentration (Vermeulen, 2007).

Table 2. Mean °brix and water activity values of five sugar free treatments of barbecue sauce and control.

Treatments* [1]	Water Activity	°Brix
XKSU	0.976[a]	11.0[a]
SK	0.977[a]	10.8[a]
XU	0.977[a]	10.9[a]
SU	0.974[a]	11.2[a]
XK	0.974[a]	10.7[a]
Control	0.951[b]	33.0[b]

1Means with different superscripts within the same column indicate significant differences between samples ($p<0.05$). *XKSU (0.1% Xanthan+1.0% Starch+0.15% Acesulfame-K+0.05% Sucralose), SK (1.5% Starch+0.25% Acesulfame-K), XU (0.25% Xanthan+0.15% Sucralose), SU (2.0% Starch+ 0.3% Sucralose), XK (0.125% Xanthan+ 0.5% Acesulfame-K), CONTROL (32% Sugar).

Total soluble solids

The absence of sugar in the sugar free treatments resulted in a 65% reduction in solid content when compared to the control formula (Table 2). The control contained 7 g of carbohydrates -per serving- more than all the sugar free treatments. However, there were no significant differences among the sugar-free treatments due to the very low amount of the other variable ingredients. This big reduction in carbohydrates content is beneficial for dietary intake planning especially for overweight and diabetic individuals – the sugar free barbecue sauces had approximately 25 less calories per serving than the control formula.

pH results

At both day 1 and day 31, the pH was not significantly different among the sugar free treatments; however, they all had a significantly lower pH than the control formula (Table 3). This is probably as a result of the lower proportion of acetic acid –contributed by vinegar, in the control formula due to the presence of sugar. At day 31, the pH of all the treatments was higher than their respective values at day 1 (Table 3). This is probably due to the buffering effect of some of the compounds present in the food products. The effect of the pH on the system components was not critical for several reasons: a- The modified waxy maize starch was chosen for optimal performance at this pH range (National, 2000); b- Sucralose degradation is minimal at this pH – 0.02% loss (Goldsmith and Merkel, 2001); c- Acesulfame-K degradation is also minimal at this pH – no loss observed (Lipinski and Hanger, 2001); d- Xanthan gum is also stable at this pH range (Whistler & BeMiller, 1993).

Table 3. Mean pH values of five treatments of sugar free barbecue sauce and control at days 1 and 31 after incubation at room temp.

Treatments*[1]	pH Day 1	Day 31
XKSU	3.77[b]	4.01[a]
SK	3.80[b]	4.00[a]
XU	3.78[b]	4.00[a]
SU	3.80[b]	4.01[a]
XK	3.78[b]	4.01[a]
Control	3.95[a]	4.08[b]

1Means with different superscripts within the same column indicate significant differences between samples ($p<0.05$). *XKSU (0.1% Xanthan+1.0% Starch+0.15% Acesulfame-K+0.05% Sucralose), SK (1.5% Starch+0.25% Acesulfame-K), XU (0.25% Xanthan+0.15% Sucralose), SU (2.0% Starch+ 0.3% Sucralose), XK (0.125% Xanthan+ 0.5% Acesulfame-K), CONTROL (32% Sugar).

Color

The measured L, a, and b color values did not show any significant differences between any of the formulations from day 1 or day 31. This was attributed to adequate preliminary work, the shelf-stability of the artificial color used, and the relatively short period of incubation.

Rheology

All treatments exhibited pseudoplastic behavior and the viscosity decreased with increasing shear rate (Figure 1). These results are in accordance with a study by Daget and Joerg (1988), using xanthan gum as a thickener in dessert creams and with the results obtained by Mandala et al. (2004). In this study, the xanthan gum was used as a thickener agent in white sauce. The values were statistically analyzed at a shear rate of approximately 50 s^{-1}, which is generally associated with the shear rate applied in the human mouth while consuming foods (Wood 1968). Although the viscosity increased at the lower temperature, the same pattern was observed between and within samples at both temperatures. Treatment SU (2.0% Starch+ 0.3% Sucralose) was significantly more viscous than the control and other treatments, while no other significant differences were noted. This could be due to the combination effect of these two ingredients. These results indicate that the usage levels of the modified waxy maize starch and/or the xanthan gum were successful in matching the viscosity of the control formula.

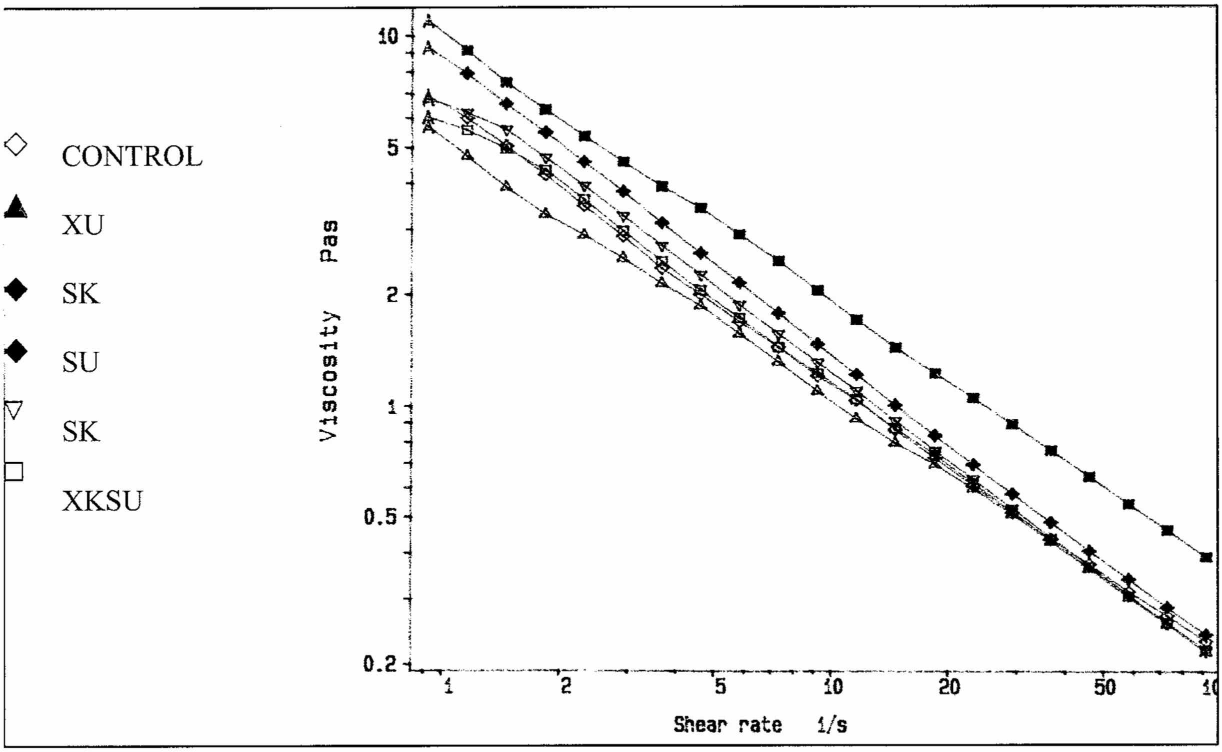

Figure 1. Viscosity measurements at various shear rates for five treatments of sugar free barbecue sauce and control.
*XKSU (0.1% Xanthan+1.0% Starch+0.15% Acesulfame-K+0.05% Sucralose), SK (1.5% Starch+0.25% Acesulfame-K), XU (0.25% Xanthan+0.15% Sucralose), SU (2.0% Starch+ 0.3% Sucralose), XK (0.125% Xanthan+ 0.5% Acesulfame-K), Control (32% Sugar).

Table 4. Sensory analysis results* of selected attributes of five treatments of sugar free barbecue sauce and control.

Treatment*	Color	Thickness	Sweet	Sour	Bitter Aftertaste	Metallic Aftertaste
XKSU**	11[a]	6[a]	7[b]	4[a]	2[a]	3[a]
SK	11[a]	5[b]	5[c]	4[a]	3[a]	2[a]
XU	11[a]	6[a]	7[b]	4[a]	2[a]	2[a]
SU	11[a]	7[a]	10[a]	4[a]	2[a]	1[b]
XK	11[a]	6[a]	6[c]	4[a]	3[a]	3[a]
Control	10[a]	6[a]	8[b]	3[a]	2[a]	2[a]

*Consensus among 5 panelists using a 1 to 15-point scale, one-point increments.

**XKSU (0.1% Xanthan+1.0% Starch+0.15% Acesulfame-K+0.05% Sucralose), SK (1.5% Starch+0.25% Acesulfame-K), XU (0.25% Xanthan+0.15% Sucralose), SU (2.0% Starch+ 0.3% Sucralose), XK (0.125% Xanthan+ 0.5% Acesulfame-K), Control (32% Sugar).

Total aerobic plate count

The microorganisms of concern in these conditions (pH 3.7-4.1) are yeasts, molds, and some spoilage bacteria (Jay, 1992). At both day 1 and day 31, the TAPC of all the treatments was below detectable levels (<10 CFU). This is a result of all the samples being processed to 195°F or above-temperature recommended for 0.5 seconds to achieve pasteurization (Jay, 1992)- and every effort was made following the Good Manufacturing Practices as they would be applied in food manufacturing, packing, or holding (USCFR, 21CFR110.3-110.110). This is an encouraging result; however, we recommend a longer incubation period to have a more accurate assessment of the possible microbial load.

Descriptive sensory analysis

Both bitter and metallic aftertastes were very low (a score of 3 or less) for all six treatments (Table 4) and cannot be solely attributed to the artificial sweeteners (they might have originated from the metal can containing the tomato sauce).

As reported by Paulus and Braun, aqueous solutions with high concentrations of acesulfame-K exhibit a bitter taste. In foods with low concentrations of acesulfame-K, this effect is not of great importance (Paulus and Braun, 1988). However, it is worth noting that the sugar free treatment with sucralose had the lowest scores for both attributes, even lower than the control. This is in accordance with sensory studies on sucralose that show that bitterness was very low in the taste profile, even comparable to the bitterness perceived from sucrose (Goldsmith and Merkel, 2001). Brown color received the same score -11- for all the sugar free treatments which was one unit higher than the score -10- attributed to the control. The control formula, the two sugar free treatments containing xanthan gum, and the sugar free treatment combining both xanthan and starch had a thickness score of 6. Both sugar free treatments containing the modified waxy maize starch rated 5 and 7. These fairly close results are comparable to the instrumental color analysis and rheological measurements. In terms of sweetness, the control scored 8. The sugar free treatment containing 0.3% sucralose had the highest sweetness score of 10. Sugar free treatments with 0.25% and 0.5% acesulfame-K rated 5 and 6, respectively. The sugar free treatment containing a combination of sucralose (0.05%) and acesulfame-K (0.15%) had a sweetness score of 7. Treatment SU (2.0% Starch+ 0.3% Sucralose) exhibited the best in all the sensory properties that were determined compare to all other treatments. It is important to note that the sensory properties and sweetness intensities at different levels of artificial sweeteners are greatly influenced by the food or beverage system in which they are studied (Wiet and Beyts, 1988).

Nutrition labeling

The serving size for barbecue sauce indicated by the RACC — Reference Amounts Customarily Consumed — is 2 tbsp (USCFR, 21CFR101.12). Thirty mL — equivalent to 2 tbsp —of all 6 formulations weighed approximately 34g. The total carbohydrate content per serving of the sugar containing control was 10 g while that of the sugar free treatments was 3g originating mainly from the tomato sauce. The control formula had 9g of sugars while the sugar free treatments had only 1g. There were 40 calories per serving for the control while the sugar free treatments had only 15 calories. The substitution of sugar had a noticeable reduction of about 65% in the caloric and carbohydrate content of the sugar free treatments as compared to the control. The remaining carbohydrates are mainly from the tomato sauce.

Conclusion

The results of this research indicate the possibility of manufacturing a sugar-free barbecue sauce that is comparable to its sugar-containing original formula. However, the process of adjusting sweetness and thickness levels is lengthy and delicate. The sensory properties of a commercial barbecue sauce formulation are complex. Therefore, it is recommended to do a complete descriptive profile of the original formulation as well as the sugar-free formulations. In addition to that, a consumer acceptability/preference is also highly recommended to determine the most liked sugar-free formulation before the product is released to the market.

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