Evaluation of Brazilian light ketchups II: quantitative descriptive and physicochemical analysis

Avaliação de catchups light do mercado brasileiro II: análise descritiva quantitativa e avaliação físico-química

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Abstract

Samples of ketchup available on the Brazilian market, one traditional (sweetened with sucrose) and three light versions (sweetened with aspartame, acesulfame-K and a blend of cyclamate, saccharin and stevia) were evaluated for their physicochemical characteristics and sensory profile (Quantitative Descriptive Analysis). Four main groups of attributes were generated: appearance, oral texture, aroma and flavor. The samples presented significant differences in all attributes, except for syneresis and overripe tomato flavor. The highest means for sweetener and bitter tastes and aftertastes were observed for the samples sweetened with acesulfame-K and the blend of sweeteners. Although different characteristics were observed among the products evaluated and, despite the differences in the formulations, the light ketchup sweetened with aspartame was the one that presented properties most similar to those of the traditional ketchup.
Keywords: *ketchup; light; sweeteners; QDA; physicochemical characteristics.*

Resumo

Amostras de catchup disponíveis no mercado brasileiro, uma tradicional (adoçada com sacarose) e três light (adoçadas com aspartame, acessulfame-K e uma combinação de ciclamato, sacarina e estévia) foram avaliadas quanto às características físico-químicas e ao perfil sensorial (Análise Descritiva Quantitativa). Quatro grandes grupos de atributos foram gerados: aparência, textura bucal, aroma e sabor. As amostras apresentaram diferença significativa em todos os atributos, exceto sinerese e tomate passado. As maiores médias para os atributos relacionados a sabor e sabor residual amargo e de adoçante foram obtidas para as amostras adoçadas com acessulfame-K e com a combinação de edulcorantes. Apesar das diferentes características observadas entre os produtos avaliados e das diferenças entre as formulações, o catchup light adoçado com aspartame foi o que apresentou propriedades mais próximas ao produto tradicional.
Palavras-chave: *catchup; light; edulcorantes; ADQ; físico-química.*

1 Introduction

Tomato (*Lycopersicum esculentum*), a fruit commonly regarded as a vegetable, is a warm season crop reasonably resistant to heat and drought (WU; NELSON, 1997). Tomatoes may be consumed fresh or, due to their perishable nature, processed to give canned whole peeled tomatoes, tomato juice, concentrated tomato juice, tomato puree or tomato paste. Tomato puree and paste may be marketed directly to the consumer or may be added as ingredients in other products, such as tomato ketchup, sauces and soups (HAYES; SMITH; MORRIS, 1998).

Tomato-based sauces comprise ketchup, tomato sauce, chili sauce and other sauces that contain tomato fruit, tomato juice, tomato concentrate or tomato particulates as the major component besides water in the formulation. These products are basically a colloidal serum containing large amounts of suspended particles and dissolved solids. The physical and chemical properties of the tomato component are among the quality determining factors. The manufacture of ketchup in a factory can start with fresh tomatoes, aseptically bulk stored tomato juice or tomato concentrates, which are mixed with proper amounts of salt, sugar, corn syrup, vinegar, onion powder, garlic powder, flavorings, spices and seasonings. Cinnamon, cassia, cloves, allspice, pepper, ginger, mustard and paprika are among the spices commonly used. Production steps include mainly preparation, heating, deaeration, homogenization, cooling and filling (WU; NELSON, 1997).

According to the Brazilian legislation (BRASIL, 2005), ketchup is a product made from mature fruits of *Lycopersicum esculentum* L. which can be added of other ingredients that

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do not interfere with the product characteristics. Sales of this product in Brazil in 2003 were around 31,000 tons, equivalent to $ 53,000 or R$ 154,000 (AC, 2004).

Sucrose is generally considered as a reference for sweet taste of foodstuffs in general, due to its sensory profile and functional properties, which may influence the body and texture of the final product. The replacement of sugar in foods and beverages is normally performed through the use of artificial sweeteners, which can also be combined with bulking agents (KILCAST, 2002).

Sweeteners are key ingredients in the development of diet/light goods, to maintain the typical and pleasant sweet taste usually given by sucrose, without adding the calories that sugar does. In the case of ketchup, to which relatively high amounts of sugar are typically added, the use of sweeteners is an interesting tool to reduce calories and provide light versions. On the other hand, the acceptance of a light product by consumers demands that the added sweetener presents, as much as possible, the same characteristics of sucrose. Sensory analysis is extremely important in such a task, as it allows the understanding of many aspects, such as the sweetness intensity of a compound in comparison to sucrose, typical taste profile in different foodstuffs, consumer acceptability and so on.

The Quantitative Descriptive Analysis (QDA) methodology (STONE et al., 1974) is one of the most used descriptive approaches and provides a complete word description for all the sensory properties of a product (STONE; SIDEL, 1993). In such a methodology, non structured linear scales are used to describe the intensity of rated attributes, with fixed verbal endpoints. Training sessions are previously performed, where 10 to 12 judges are exposed to as many possible variations of the product under study as possible and, through consensus, a standardized vocabulary is developed to describe the sensory differences among the samples, including reference standards and/or verbal definitions that should be used for the descriptive terms. The actual product evaluations are individually performed by each judge. The resulting data can be analyzed statistically, using Analysis of Variance and multivariate statistical techniques (LAWLESS; HEYMANN, 1999).

The QDA methodology was used for ketchup evaluation by Porreta (1991) (BRASIL, 2005), to compare eighteen different commercial products from Italy and the USA, regarding both physicochemical properties and sensory profile. According to the author, this method was useful in describing the differences among the various products evaluated. Porreta e Birzi (1995) used QDA to study the effect of storage temperature on the shelf-life of ketchups produced with two different vinegars (spirit and wine). QDA was also performed by Varela et al. (2003) to evaluate the effect of different thickening agents on the texture of ketchup and, in this study, sensory and instrumental measurements were correlated.

Ketchup of uniform color, consistency and flavor can only be produced by controlling the quality and amount of each ingredient used in the formulation. The typical tomato flavor and consistency of the finished product depend largely on the tomato solids used in each batch. In general, the physicochemical methods of analysis used with ketchup are similar to those applied for tomato pulp (GOULD, 1992). The main analysis that are usually performed to evaluate such products are: total solids, soluble solids, water insoluble solids, ascorbic acid, color, consistency, pH, acidity, sugar and salt (sodium chloride) (DENNY, 1997; GOOSE; BINSTED, 1973; HAYES; SMITH; MORRIS, 1998; PORRETA et al., 1993).

According to the World Health Organization (WHO), the intake of free sugars in excessive amounts represents a risk to the nutritional quality of the human diet, as they provide high amounts of energy, without adding nutrients. The recommendation is that the intake of free sugars represents not more than 10% of the total energy intake (WHO, 2003). Additionally, obesity represents at present one of the main concerns in terms of public health. The world population of obese people was estimated in 300 million in 2005 (WHO, 2005).

Ketchup was chosen for this evaluation as it is a popular food in Brazil and typically rich in sucrose, so it is very important that versions with less or no sugar are available for the consumers who care about health or need to reduce sugar in the diet. The sensory and physicochemical evaluation of the light ketchups currently available in the Brazilian market will provide a better knowledge of such kind of product and, if associated to consumer acceptance information, can help food developers to deliver reduced-sugar or sugar-free versions that really meet consumers' expectations.

The objective of this study was to compare the sensory profile, through Quantitative Descriptive Analysis (QDA) and physicochemical characteristics of 4 commercial ketchups, one sweetened with sucrose and 3 sweetened with high intensity sweeteners (aspartame; acesulfame-K; cyclamate/saccharin/stevia). These samples were assessed in a previous study performed by Bannwart et al. (2006) regarding time-intensity characteristics and consumer acceptance. The present study aimed to complement the previous one, as no studies were found in the literature in terms of the performance of different high-intensity sweeteners in this kind of product using QDA.

2 Materials and methods

2.1 Samples

The commercial samples evaluated in the present study were one regular and three light ketchups, purchased in supermarkets in the city of Campinas, SP - Brazil, as described bellow:

- *Brand 1*: regular ketchup, sweetened with sucrose;
- *Brand 2*: light ketchup, sweetened with aspartame;
- *Brand 3*: light ketchup, sweetened with acesulfame-K; and
- *Brand 4*: light ketchup, sweetened with cyclamate, saccharin and stevia.

2.2 Sensory analysis

Pre-selection of panelists

A group of eleven women were pre-selected for the descriptive analysis, based on their previous experience in evaluating ketchup and their ability to discriminate sensory differences in this kind of product. All of them were accustomed to evaluate tomato products through QDA analysis for several years, so no pre-selection analyses were performed.

Development of descriptive terminology

The pre-selected judges met 4 times to develop the sensory describing terms to be used in the definitive tests. In this step, the Repertory Grid Kelly's Method (MOSKOVITZ, 1983) was used in an open discussion. Samples of regular and light ketchups were evaluated in pairs and their similarities and differences were reported in a form.

After the generation of the describing terms, an evaluation form composed of non structured 10 cm scales, one for each descriptive sensory term, was elaborated. Through consensus, the group defined reference materials to help in the identification of all sensory characteristics of the products and to anchor the extreme points of the intensity scales.

Selection and training of the definitive panel

The pre-selected panel was trained for the accomplishment of the Quantitative Descriptive Analysis (STONE; SIDEL, 1993). Three training sessions were conducted, when the judges reviewed the definitions of the sensory describing terms and the references developed, and then evaluated different samples of regular and light ketchup, to fix the sensory memory and to practice using the developed form.

In order to select the definitive panel for the Quantitative Descriptive Analysis, tests were applied to all the judges using the form with the intensity scales for the sensory terms developed in the previous step. The final judges were selected based on their capacity to discriminate among different samples, repeatability and agreement with the group (DAMÁSIO; COSTELL, 1991). Analysis of Variance of 2 factors (sample and repetition) was performed for each panelist with respect to each attribute and the judges were selected according to values of significant F_{sample} ($p < 0.30$) and non significant $F_{repetition}$ ($p > 0.05$). For this selection, the 11 candidates evaluated the 4 samples of commercial light ketchups in 3 repetitions, with respect to the pre-determined attributes. The agreement of the sensory panel was also verified in this step: the judges' individual means should be similar among each other and also close to the panel's means for all the evaluated attributes and the interaction sample x judge should be non significant ($p > 0.05$).

Sensory analysis

The selected and trained panelists participated in the sensory tests of the regular and light ketchups under study, when the products were assessed in individual booths. The samples (5 mL each) were served in plastic cups coded with 3 digits. All the products were evaluated in monadic presentations, in 4 random repetitions.

Data analysis

The final selection of panelists for the Quantitative Descriptive Analysis was through a two-factor Analysis of Variance (sample and repetition) for each individual with respect to each attribute (MEILGAARD, 1999). The judges with significant F_{sample} values ($p < 0.30$) and non significant $F_{repetition}$ values ($p > 0.05$) were selected. The data obtained through QDA were evaluated using Analysis of Variance (ANOVA), the Tukey test of averages and Principal Component Analysis (PCA). All the statistical analyses were carried out using the SAS program (SAS, 2003).

2.3 Physicochemical analyses

The four samples of ketchups submitted to sensory analysis were also assessed for their physicochemical profile. Three samples of each brand were analyzed regarding the following parameters:

- pH: measured using a Model B474 (Micronal) digital pH-meter, according to AOAC method 981.12 (AOAC, 1996);
- Acidity: determined as acetic acid, by titration, following AOAC method 935.57 (AOAC, 1996);
- Salt: determined by direct titration (Mohr) method, as described by Goose e Binsted (1973);
- Consistency: using a Bostwick consistometer, by measuring the flow of undiluted product in 30 seconds, at room temperature, as described by Goose e Binsted (1973);
- Hunter color: measured using a Model D25 A Optical Sensor Hunterlab colorimeter (Hunter Associated Laboratories, USA), in terms of L, a, b and TCS (Total Catchup Score - $TCS = -74.937 + 7.5172a - 0.1278a^2 - 0.8051b$) (GOOSE; BINSTED, 1973);
- Soluble solids (Brix): measured using a Model 10460 (American Optional, USA) ABBE refractometer, according to AOAC method 970.59 (AOAC, 1996); and
- Total solids: determined using a Smart System 5 (CEM) equipment, according to AOAC method 985.226 (AOAC, 1996).

3 Results and discussion

3.1 Sensory analysis

The 11 pre-selected candidates were selected for the definitive tests, based on their ability to discriminate samples ($p\ F_{sample} < 0.30$) and repeatability ($p\ F_{repetition} > 0.05$). The results of this selection are shown in Tables 1 (F_{sample}) and 2 ($F_{repetition}$). The previously approved judges, based on the values of F_{sample} and $F_{repetition}$, were definitively selected, as no discrepancies were observed among them.

Table 1. Significance levels (p) for the judges with respect to the discrimination of samples (F_{sample}).

Attributes		Judges										
		1	2	3	4	5	6	7	8	9	10	11
Appearance	Color	0.0002	0.0021	0.0374	0.0050	0.0241	0.0003	0.0002	<0.0001	0.2425	0.0415	0.0008
	Consistency (visual)	0.0235	0.2145	0.0024	0.0009	0.0028	0.0317	0.1489	0.1116	<0.0001	0.2478	0.0039
	Sandiness (visual)	0.0008	0.0025	0.0036	0.0007	0.0215	0.254	0.0024	0.0003	0.0123	0.0088	0.0648
	Gumminess	0.0068	0.0031	<0.0001	0.0785	0.1283	0.1470	0.0058	0.0009	0.0034	0.0069	0.0205
	Brightness	0.0001	0.0025	0.0007	0.0027	0.2008	0.1200	0.0006	0.0104	0.0022	0.0005	0.0117
	Particles	0.0004	0.0987	0.1140	0.0007	0.0033	<0.0001	<0.0001	0.0158	0.0111	0.0104	0.0225
	Syneresis	0.0021	0.0049	0.0416	0.0009	0.0008	0.0008	0.0027	0.0519	0.0023	0.0005	0.0247
Oral texture	Sandiness (oral)	0.0066	0.0012	0.0004	0.0098	0.0117	0.0105	0.0009	0.0028	0.0553	0.0997	0.0222
	Consistency (oral)	0.2320	0.1040	0.0034	0.0087	0.1058	0.0012	0.0014	0.0009	0.1105	0.0015	0.0119
	Mouthfeel	0.0227	0.0045	0.0225	0.0209	0.0055	0.0854	0.1007	0.0099	0.0203	0.0055	0.0059
	Astringency	<0.0001	0.0002	0.0011	0.128	0.0099	0.0984	0.0055	0.0027	0.0009	0.0036	0.1008
	Sweetener aftertaste	0.0104	0.1055	0.0077	0.0125	0.1008	0.0008	0.0058	0.0026	0.2004	0.0874	0.0085
	Bitter aftertaste	0.0584	0.0107	0.1120	0.0056	0.0089	0.0587	0.0077	0.0745	0.0158	0.0269	0.0007
Aroma	Vinegar	0.0014	0.0008	0.0117	0.0058	0.0044	0.0021	0.0102	0.2004	0.0058	0.0021	0.0211
	Pungent	0.0026	0.0037	0.0221	0.0007	<0.0001	0.0009	0.0004	0.0578	0.0124	0.0306	0.0587
	Cloves	0.0417	0.0555	0.0022	0.2140	0.0015	0.0006	0.0019	0.0208	0.2000	0.1789	0.0011
	Cinnamon	0.0069	0.0009	0.0896	0.0088	0.0009	0.0074	0.0009	0.0554	0.0088	0.0028	0.0008
	Nutmeg	0.1008	0.1050	0.0007	0.0148	0.0326	0.0444	0.0052	0.0003	0.0521	0.0087	0.0021
Flavor	Salty	0.0004	0.0075	0.0085	0.0024	0.0033	0.0183	0.0877	0.0654	0.0066	0.0009	0.0004
	Sweet	0.0022	0.0239	0.0054	0.0050	0.0024	0.0070	0.0497	0.0033	0.0109	0.0480	0.0079
	Acid	0.0001	0.0028	0.0267	0.1077	0.1104	0.0055	0.0269	0.0334	0.0011	0.0008	0.0475
	Bitter	0.0010	0.0587	0.0995	0.1004	0.0005	0.0008	0.0004	0.1072	0.0104	0.0087	0.0044
	Tomato taste	0.0214	0.0447	0.0005	0.0199	0.0369	0.0044	0.0002	0.0127	0.1007	0.0088	0.0070
	Overripe tomato	0.0004	0.0001	0.0012	0.0051	0.0016	0.0022	0.2011	0.0236	0.0574	0.0699	0.0907
	Pepper	0.0001	<0.0001	0.0004	0.0570	0.0098	0.0507	0.0051	0.0039	0.0307	0.0221	0.0857
	Spice	0.0007	0.0504	0.0501	0.0666	0.0584	0.0044	0.0210	0.0011	0.0069	0.0009	0.0027
	Clove taste	0.0003	0.0708	0.0551	0.0041	0.0030	0.0504	0.0033	0.0508	0.0888	0.0027	0.0008
	Cinnamon taste	0.0041	0.0004	0.0028	0.0205	0.0570	0.0555	0.0987	0.0220	0.0001	0.0087	0.0508
	Nutmeg taste	0.0027	0.0002	0.0003	0.0407	0.0005	0.0699	0.0225	0.0080	0.0099	0.0007	0.0006
	Sweetener taste	0.0020	0.0004	0.0107	0.0999	0.0504	0.0336	0.0587	0.0055	0.0603	0.0875	0.0663

Judges with values of p $F_{sample} < 0.30$; and p $F_{repetition} > 0.05$ were selected.

The sensory describing terms developed by the judges, used for the final assessment of the ketchup samples, are presented in Table 3, together with the definitions and references established for such terms. The attributes developed were divided in 4 main groups: appearance, oral texture, aroma and flavor.

The mean scores for each sample regarding the attributes evaluated are shown in Table 4. The results of the Principal Component Analysis (PCA) are presented in Figures 1 (appearance and oral texture) and 2 (aroma and flavor). As it can be observed from Table 4, all the ketchup brands evaluated had very different sensory profiles. It can be observed that the samples presented significant differences in all attributes, except for syneresis and overripe tomato flavor. For these two attributes, all the means were zero or close to zero.

In terms of appearance and oral texture, sample 1 (formulated with sucrose) showed higher means for color, consistency (both visual and oral), gumminess and mouthfeel. Sample 2 (sweetened with aspartame) exhibited higher means for sandiness (visual and oral) and astringency and sample 4 (sweetened with a blend of cyclamate, saccharin and stevia) presented the highest mean for brightness. In the attributes sweetener and bitter aftertastes, sample 3 (formulated with acesulfame-K) and 4 were the ones that presented the highest means. Syneresis was not noticed in any of the samples evaluated and, regarding

Table 2. Significance levels (p) for the judges with respect to repeatability ($F_{repetition}$).

Attributes		Judges										
		1	2	3	4	5	6	7	8	9	10	11
Appearance	Color	0.5770	0.3225	0.0798	0.1225	0.1478	0.2697	0.3698	0.8970	0.2580	0.2470	0.6781
	Consistency (visual)	0.1287	0.0998	0.1377	0.2890	0.8741	0.6900	0.2841	0.3687	0.4001	0.3366	0.2178
	Sandiness (visual)	0.0997	0.1890	0.7784	0.6570	0.5008	0.2778	0.0991	0.4782	0.3496	0.2258	0.1471
	Gumminess	0.1258	0.1124	0.7877	0.5471	0.2125	0.3983	0.2009	0.2874	0.2000	0.3998	0.4470
	Brightness	0.8057	0.5507	0.3028	0.3369	0.8710	0.2421	0.3650	0.2278	0.5740	0.3587	0.6654
	Particles	0.5200	0.6984	0.7471	0.3227	0.0066	0.0991	0.3582	0.4478	0.5963	0.3987	0.3887
	Syneresis	0.3552	0.3330	0.4748	0.4005	0.5774	0.1008	0.2214	0.2987	0.2914	0.1552	0.3944
Oral texture	Sandiness (oral)	0.6960	0.3581	0.6510	0.1947	0.2845	0.5556	0.6303	0.6667	0.8056	0.4474	0.3211
	Consistency (oral)	0.5700	0.5447	0.4999	0.5820	0.3690	0.6352	0.2574	0.5507	0.5141	0.6504	0.7170
	Mouthfeel	0.3342	0.3504	0.8654	0.2587	0.3237	0.5580	0.2009	0.1872	0.2990	0.3225	0.3336
	Astringency	0.6074	0.5821	0.5029	0.6087	0.6677	0.5239	0.2540	0.1088	0.2369	0.3505	0.6707
	Sweetener aftertaste	0.4987	0.3258	0.6200	0.7141	0.4190	0.5123	0.4873	0.4257	0.3369	0.2574	0.2258
	Bitter aftertaste	0.2710	0.6541	0.5326	0.1597	0.4185	0.3368	0.7435	0.6984	0.2544	0.2158	0.3325
Aroma	Vinegar	0.1245	0.5848	0.3658	0.2255	0.2709	0.2006	0.2371	0.5589	0.8887	0.3698	0.2148
	Pungent	0.1458	0.1231	0.5282	0.7439	0.2896	0.5478	0.2247	0.2829	0.1748	0.6981	0.2658
	Cloves	0.4158	0.2877	0.2250	0.3162	0.6888	0.0997	0.1258	0.3658	0.7421	0.6252	0.3667
	Cinnamon	0.5874	0.5004	0.2569	0.1069	0.2447	0.7403	0.7772	0.0997	0.2228	0.2684	0.3336
	Nutmeg	0.5698	0.5310	0.4447	0.6478	0.6007	0.5893	0.5554	0.3288	0.5670	0.1009	0.2874
Flavor	Salty	0.2101	0.5591	0.3286	0.3337	0.2987	0.2515	0.2269	0.3841	0.3300	0.1989	0.4104
	Sweet	0.7410	0.5519	0.6586	0.6363	0.5219	0.4474	0.5891	0.1184	0.0994	0.1189	0.2274
	Acid	0.6878	0.5812	0.4473	0.3682	0.2005	0.3281	0.6918	0.5473	0.5123	0.4421	0.3741
	Bitter	0.4172	0.4099	0.3227	0.3684	0.2999	0.2541	0.3918	0.2779	0.5813	0.6687	0.5988
	Tomato taste	0.2121	0.3099	0.0918	0.7470	0.4478	0.6697	0.3656	0.3110	0.4423	0.8040	0.6667
	Overripe tomato	0.1705	0.5814	0.6626	0.4184	0.7700	0.3254	0.7107	0.4118	0.4007	0.3996	0.2741
	Pepper	0.3078	0.4555	0.4741	0.3287	0.3009	0.0947	0.1899	0.3631	0.3007	0.4250	0.3999
	Spice	0.2587	0.2120	0.3874	0.3040	0.3689	0.4172	0.5743	0.2389	0.6872	0.2256	0.3214
	Clove taste	0.2236	0.2178	0.3994	0.2743	0.5506	0.6079	0.5898	0.2100	0.3465	0.7894	0.6874
	Cinnamon taste	0.3314	0.2587	0.2007	0.6870	0.6993	0.3678	0.2523	0.2177	0.2904	0.3706	0.2840
	Nutmeg taste	0.1904	0.1451	0.5553	0.3284	0.1185	0.2867	0.6882	0.3388	0.4597	0.1029	0.3468
	Sweetener taste	0.5062	0.2783	0.3564	0.6973	0.5589	0.3648	0.5897	0.6997	0.5269	0.2245	0.2973

Judges with values of p $F_{sample} < 0.30$; and p $F_{repetition} > 0.05$ were selected.

astringency, the behavior of all samples was quite similar, the highest mean presented by sample 2 and only samples 2 and 4 exhibiting a significant difference in this attribute.

With respect to aroma and flavor, sample 1 was considered saltier only in comparison to sample 4. Also, this sample was sweeter and with more tomato and spice flavor than the three light samples. Sample 2 showed the highest mean for clove aroma and pepper flavor. In the attributes bitter and sweetener, higher means were observed for samples 3 and 4. Samples 1 and 2 presented lower means for these attributes and differed significantly from the other samples.

Despite the differences in the overall sensory profile observed among the different brands of ketchup evaluated in this study, the sample sweetened with aspartame (sample 2) was the most similar to the regular ketchup (sample 1) with regard to the attributes related to sweetener flavor and sweetener/bitter aftertaste. A similar conclusion was reported by Bannwart et al. (2006), through time-intensity and preference studies, performed with the same samples.

Comparing the results of a consumer acceptance test also performed by Bannwart et al. (2006) with the same commercial samples of ketchup evaluated in the present study, one can conclude that strong red color, high consistency and mouthfeel, pronounced sweet taste, tomato taste and spices are desirable characteristics for ketchup, while sweetener and bitter tastes

Table 3. Sensory describing terms developed for ketchup samples.

Sensory describing terms		Definitions	References
Appearance	Color	Scale from orange to brown	0 - Diluted tomato pulp (2 °Brix) 10 - Tomato pulp (29 °Brix) + 0.2% caramel color
	Consistency (visual)	Sensation of soft/consistent while mixing with a spoon	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (18 °Brix) + 2% water
	Sandiness (visual)	Amount of lumps that can be seen in the sample	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (18 °Brix) + 2% water
	Gumminess	Cream aspect of the product	0 - Tomato pulp (18 °Brix) + 15% water 10 - Diluted tomato pulp (2 °Brix) + 2.5% native starch
	Brightness	Shine aspect seen while mixing the product	0 - Tomato pulp (14 °Brix) 10 - Tomato pulp (8 °Brix), homogenized
	Particles	Amount of particles seen when the product is spread on a plate	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (8 °Brix) + 0.15% black pepper
	Syneresis	Liquid phase that is formed around a portion of ketchup in a plate	0 - Diluted tomato pulp (2 °Brix) + 0.2% caramel color 10 - Tomato pulp (8 °Brix) + mashed tomatoes (1:1)
Aroma	Vinegar	Flavor characteristic of pure vinegar	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 20% vinegar (9% acetic acid)
	Pungent	Sensation of burning in the nose, reminds acid	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 30% vinegar (9% acetic acid)
	Cloves	Perception of clove flavor	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 0.02% clove essential oil (10% concentration)
	Cinnamon	Perception of cinnamon flavor	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 0.02% cinnamon essential oil (10% concentration)
	Nutmeg	Perception of nutmeg flavor	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 0.02% nutmeg essential oil (10% concentration)
Oral texture	Sandiness (oral)	Sensation of sandy particles on the tongue	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (18 °Brix)
	Consistency (oral)	Sensation of heavy/light or hard/soft when pressing the tongue against the palate	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (18 °Brix)
	Mouthfeel	Sensation of filling the mouth; related to disappearing fast or slowly from the mouth	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (8 °Brix) + 1.5% modified starch
	Astringency	Sensation of tying the mouth up	0 - Tomato pulp (10 °Brix) 10 - Tomato pulp (10 °Brix) + 1.0% salt + 0.02% nutmeg essential oil (10% concentration)
	Sweetener aftertaste	Sweet/artificial taste that remains in the mouth after rinsing with water	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (8 °Brix), homogenized + 0.2% sucralose
	Bitter aftertaste	Bitter taste that remains in the mouth after rinsing with water	0 - Tomato pulp (8 °Brix), homogenized 10 - Tomato pulp (8 °Brix), homogenized + 0.175% saccharin + 0.25% caffeine
Flavor	Salty	Intensity of salty taste	0 - Tomato pulp (10 °Brix) 10 - Tomato pulp (10 °Brix) + 2.5% salt
	Sweet	Intensity of sweet taste	0 - Tomato pulp (10 °Brix) 10 - Tomato pulp (10 °Brix) + 10% refined sugar
	Acid	Intensity of acid taste	0 - Tomato pulp (10 °Brix) 10 - Tomato pulp (10 °Brix) + 2% citric acid
	Bitter	Bitter taste that remains in the mouth	0 - Pure water 10 - Caffeine (aqueous solution, 0.04%)
	Tomato	Intensity of tomato taste	0 - Diluted tomato pulp (2 °Brix) 10 - Tomato pulp (24 °Brix)
	Overripe tomato	Taste of fermented/not fresh tomatoes	0 - Tomato pulp (10 °Brix) 10 - Grinded overripe tomatoes (passed through a sieve)
	Pepper	Characteristic taste of black pepper/burning	0 - Tomato pulp (10 °Brix) 10 - Tomato pulp (10 °Brix) + 0.2% black pepper
	Spice	Intensity of spice taste, mainly onion and garlic	0 - Tomato pulp (10 °Brix) 10 - Tomato pulp (10 °Brix) + 0.15% Ketchup Flavor (Symrise 139802)
	Cloves	Intensity of clove taste	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 0.02% clove essential oil (10% concentration)

Table 3. Continued...

Sensory describing terms		Definitions	References
Flavor	Cinnamon	Intensity of cinnamon taste	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 0.02% cinnamon essential oil (10% concentration)
	Nutmeg	Intensity of nutmeg taste	0 - Tomato pulp (8 °Brix) 10 - Tomato pulp (8 °Brix) + 0.02% nutmeg essential oil (10% concentration)
	Sweetener	Artificial sweet taste that reminds tabletop sweeteners and medicine	0 - Tomato pulp (8 °Brix), homogenized 10 - 0.002% Neotame

Table 4. Mean QDA scores for ketchup samples.

	Attributes	1	2	3	4	MSD
Appearance	Color	5.61^{a}	4.34^{c}	2.48^{d}	5.02^{b}	0.51
	Consistency (visual)	6.86^{a}	4.34^{b}	2.75^{c}	3.09^{c}	0.50
	Sandiness (visual)	1.77^{c}	5.11^{a}	3.05^{b}	0.45^{d}	0.61
	Gumminess	6.00^{a}	2.82^{b}	1.23^{c}	2.91^{b}	0.62
	Brightness	7.14^{b}	6.00^{c}	6.00^{c}	8.14^{a}	0.61
	Particles	1.00^{c}	5.55^{a}	2.70^{b}	5.05^{a}	0.76
	Syneresis	0.00^{a}	0.00^{a}	0.00^{a}	0.14^{a}	0.42
Oral Texture	Sweetener aftertaste	0.32^{c}	1.64^{b}	4.91^{a}	5.00^{a}	0.65
	Bitter aftertaste	0.00^{c}	0.59^{c}	2.66^{a}	1.55^{b}	0.66
	Sandiness (oral)	0.64^{c}	3.43^{a}	1.41^{b}	0.41^{c}	0.66
	Consistency (oral)	6.77^{a}	3.70^{b}	2.41^{c}	2.68^{c}	0.56
	Mouthfeel	6.59^{a}	3.61^{b}	2.45^{c}	2.68^{c}	0.57
	Astringency	3.77^{ab}	4.59^{a}	3.77^{ab}	3.00^{b}	0.84
Aroma	Vinegar	5.09^{a}	5.30^{a}	5.36^{a}	3.48^{b}	0.88
	Pungent	6.64^{a}	6.05^{a}	6.36^{a}	4.23^{b}	0.71
	Cloves	2.23^{c}	4.68^{a}	1.68^{c}	3.05^{b}	0.61
	Cinnamon	2.50^{b}	3.91^{a}	2.14^{b}	4.41^{a}	0.79
	Nutmeg	3.73^{a}	3.14^{ab}	2.27^{c}	2.50^{bc}	0.74
Flavor	Salty	3.48^{a}	3.05^{ab}	3.30^{ab}	2.80^{b}	0.52
	Sweet	7.25^{a}	5.82^{b}	3.55^{d}	4.52^{c}	0.72
	Acid	6.61^{a}	6.27^{a}	6.16^{a}	4.95^{b}	0.47
	Bitter	0.00^{b}	0.73^{b}	2.27^{a}	1.59^{a}	0.73
	Tomato	7.16^{a}	5.34^{b}	4.16^{c}	4.05^{c}	0.92
	Overripe tomato	0.00^{a}	0.41^{a}	0.09^{a}	0.00^{a}	0.54
	Pepper	0.68^{b}	3.45^{a}	0.82^{b}	1.68^{b}	1.08
	Spice	8.05^{a}	5.00^{b}	4.73^{b}	4.41^{b}	1.00
	Cloves	2.45^{b}	5.14^{a}	2.50^{b}	4.45^{a}	0.73
	Cinnamon	3.41^{b}	4.64^{a}	2.14^{c}	4.50^{a}	0.78
	Nutmeg	3.95^{a}	3.41^{ab}	2.27^{c}	2.95^{bc}	0.70
	Sweetener	0.61^{d}	1.86^{c}	4.95^{b}	6.75^{a}	0.95

MSD = minimum significant difference (Tukey test of averages); and Means with the same letters on the same line are not significantly different ($p \leq 0.05$).

and aftertastes are negative aspects related to the product's acceptance.

Not many studies related to the sensory evaluation of ketchup are available in the literature consulted and none was found on sweeteners in such an application.

Porretta e Birzi (1995) used QDA to evaluate two different ketchups, one formulated with wine vinegar and the other with spirit vinegar, during their shelf-life at different temperatures. The attributes evaluated in such study were: sucrose, fructose, consistency, glucose, volatile acidity, glutamic acid and total acidity, which were considered the most relevant for this kind of product. Based both on the QDA and physicochemical results, the authors concluded that the wine-vinegar ketchup had a shorter shelf-life than the spirit-vinegar product. Also, uncontrolled storage conditions significantly shortened the shelf-life of the products.

Varella et al. (2003) evaluated the effect of different thickeners on ketchup texture, through both instrumental and sensory analysis (texture QDA). Samples with higher concentrations of guar and xanthan gums, as well as their combination, scored higher in desirable sensory attributes in ketchup.

With the data collected for the four commercial samples of ketchup, Principal Component Analysis (PCA) was performed. The results are shown in Figures 1 and 2, for the attributes related to appearance and oral texture and for aroma and flavor, respectively.

Regarding appearance and oral texture, principal components 1 and 2 explained, respectively, 54.6 and 33.9% of the variability among the samples. Sample 1 was characterized by the attributes consistency (visual and oral), mouthfeel, color and gumminess. Sample 2 was characterized by sandiness (visual and oral) and astringency. The attributes that characterized sample 3 were particles and bitter aftertaste. Sample 4 was characterized by brightness and sweetener aftertaste.

In terms of the attributes related to aroma and flavor, 50.2% of the variability among the samples was explained by component 1 and 34.2% by component 2. Samples 1 and 2 were characterized by most of the attributes, mainly tomato, spices, acid, vinegar, pungent salty and sweet (in the case of sample 1) and clove aroma, cinnamon, nutmeg, cloves, sweet and pepper (in the case of sample 2). Samples 3 and 4 presented similar behavior and were characterized by bitter and sweetener tastes.

It can be observed that the four samples evaluated showed distinct sensory profiles, mainly regarding the attributes related to appearance and oral texture.

3.2 Physicochemical analyses

The results of the physicochemical analysis are shown in Table 5. The samples analyzed were very similar regarding pH, with the highest mean observed for sample 4, which also presented a much lower acidity compared to the other samples. The remaining 3 samples presented very similar means for acidity. These observations are in agreement with the sensory results.

Samples 2, 3 and 4 were very similar regarding salt content, but sample 1 showed a higher mean for this parameter, compared to the other 3 samples, which is also in accordance with the sensory results.

In terms of consistency, sample 1 presented the lowest Bostwick mean, followed by sample 2, while the other 2 samples had similar results for this parameter. The same observations were made in the QDA. Regarding solids content (both soluble and total), proximate results were observed for samples 1 and 2, but lower means were observed for the other 2 samples.

Regarding color, samples 1 and 2 were very similar in all parameters. Sample 3 presented higher means for the parameters L and a (lighter, with a stronger red color) and also the highest

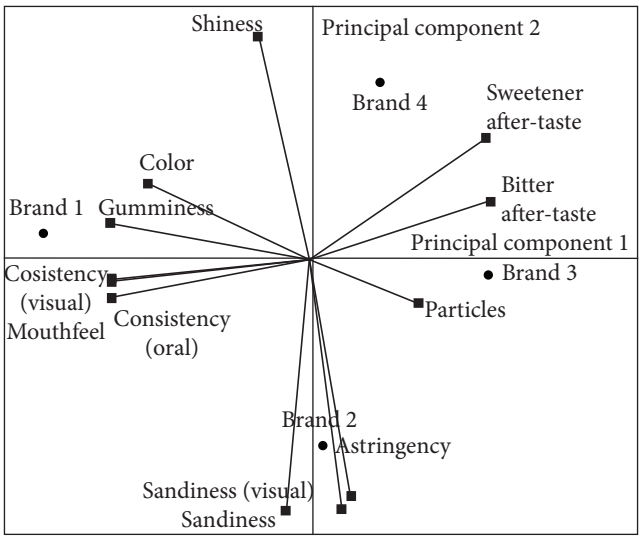

Figure 1. Principal Component Analysis for appearance and oral texture of ketchup samples.

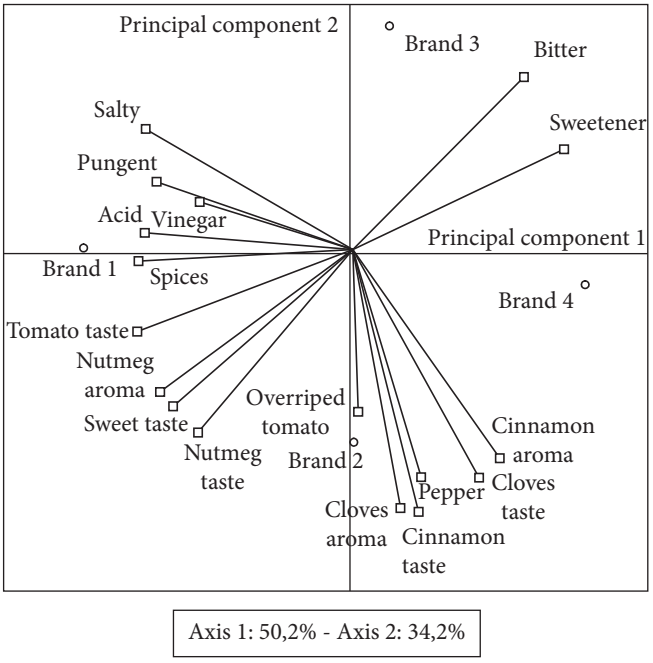

Figure 2. Principal Component Analysis for aroma and flavor of ketchup samples.

Table 5. Physicochemical characteristics of commercial ketchup samples**.

Brand	Acidity (% acetic acid)	pH	Salt (%)	Soluble solids (%)	Total solids (%)	Bostwick consistency (cm/30 s)	Color			
							L	a (+)	b (+)	TCS*
1	1.49 ± 0.15	3.70 ± 0.07	3.31 ± 0.19	33.24 ± 0.39	31.21 ± 0.18	2.9 ± 0.4	20.2 ± 0.1	20.1 ± 0.1	10.4 ± 0.1	16.2 ± 0.1
2	1.61 ± 0.12	3.80 ± 0.08	2.20 ± 0.16	26.68 ± 0.46	27.21 ± 0.27	8.7 ± 0.9	22.3 ± 0.1	20.7 ± 0.5	10.8 ± 0.4	17.3 ± 0.5
3	1.53 ± 0.08	3.78 ± 0.01	2.52 ± 0.12	11.36 ± 0.13	12.08 ± 0.16	11.4 ± 0.1	26.1 ± 0.4	23.9 ± 0.3	14.9 ± 0.4	19.7 ± 0.4
4	0.51 ± 0.16	3.91 ± 0.05	2.27 ± 0.10	10.39 ± 0.23	12.12 ± 0.21	12.1 ± 0.8	20.2 ± 0.4	18.3 ± 0.4	7.2 ± 0.2	14.0 ± 0.3

*TCS = – 74.937 + 7.5172a – 0.1278a^2 – 0.8051b; and **the values are the means of three repetitions (± standard deviation).

mean for b (more yellow) compared to the others. Sample 4 exhibited the lowest means for all the color parameters evaluated. In the sensory evaluation, all the 4 samples differed significantly, sample 1 being the darkest one, followed by 4, 2 and 3.

4 Conclusions

The sample sweetened with sucrose stood out against the samples formulated with sweeteners in the attributes related to appearance, as being more consistent, darker and gummier. This same sample presented more tomato taste than the others.

Regarding the attributes related to sweeteners, which are of great importance in this study, the samples formulated with acesulfame-K and with the cyclamate/saccharin/stevia blend showed a significantly higher perception of sweetener aftertaste, compared to the sample formulated with aspartame. In terms of bitter aftertaste, the sample with added acesulfame-K was the one that exhibited the highest perception. Finally, the sample formulated with the blend showed the highest score for sweetener taste, followed by the samples sweetened with acesulfame-K and aspartame, respectively. One can conclude that out of the three light ketchups evaluated in the present study, the one formulated with aspartame was less characterized by the attributes related to sweetener perception, when compared to the other two samples.

The physicochemical results were, in general, in line with the sensory results, mainly regarding salt content, acidity and consistency.

It is important to point out that the overall differences observed among the products evaluated are directly related to differences in their formulations, as each of them is produced by a different company. In this aspect, it is important to mention that up to now the Brazilian regulatory authorities have not developed a standard for light ketchup and, due to this, a wide variety of formulations of light ketchup are available on the market. From the results of the present study and, considering the specific formulation of each sample evaluated, that can interfere in some of the sensory attributes, one can conclude that the sweetener that seems to better replace sugar in such an application is aspartame. The same conclusion was also obtained in the previous study performed by Bannwart et al. (2006).

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