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Sensory profile, consumer preference and chemical composition of craft beers from Brazil

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Abstract

The craft beers are outlined as a distinctively flavored, brewed and distributed regionally, using top-fermenting (ale) yeast, bottom-fermenting (lager) yeast or spontaneously fermentation. Craft beers are largely consumed and produced in Brazil and presents great level of polyphenols, which would affect the consumer's preference. In this way, we analyzed the relation between polyphenols, bitterness and composition of main different styles of craft beers and the consumer´s preference. Six different styles were analyzed according its polyphenol content, bitterness, chemical composition, sensory profile and preference. For preference, a panel with 62 non-trained assessors was used. For sensory profile, the quantitative descriptive analysis was performed, using expert assessors (n=8). The preferred style was Classic American Pilsner and the style less preferred was Standard American Lager. The craft beer more preferred showed a decreased bitterness (9.52), polyphenol content (0.61 mg EAG/mL), total solids (6.75 ºBrix) and turbidity (7.27 NTU). This beer exhibited reduced sensory notes of malty, fruity, smoked, hoppy and phenolic, but a higher perception of floral, sweet and yeast notes. The bitter attribute has a reduced perception. This study advances understanding the sensory profile and complexity of craft beers styles from Southern Brazilian.

Keywords: craft beer; polyphenols; bitterness; preference; sensory attributes

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1. Introduction

The beer can be defined as a product of cereal fermentation process and consists of more than 90% water, in addition to carbohydrates, minerals and alcohol (on average 3.5 to 10%) [1]. Beer is the alcoholic beverage more consumed worldwide [2]. According Brazilian laws, the beer is an alcoholic beverage fermented, with 0.5% (v/v) or superior ethanol content, obtained from barley malt and potable water by yeasts action and added of hop [3]. The different combinations of ingredients and brewing processes yield a chemically complex product, which present numerous types and styles [4].

Last year, Brazil produced 13.9 billion liters and consumed 1.25 billion liters, which represented 7.0% and 6.6%, respectively, of global beer market [4]. In last years it was verified a great increase in Brazilian market, mainly in craft beers consume and production. Craft beers can be defined as a distinctively flavored beer, brewed and distributed regionally and surge in popularity benefited from innovation, creativity, typicality, and authenticity that typify craft beer as an experience delivering drink that offers pleasure, enjoyment, sense of identity and belonging, selffulfillment, social recognition, and sustainability [5].

The consumers chosen craft beers because it has a variety of flavors such as malted barley, chestnut and honey-flavored beers that increase the probability of perceiving craft beers to have a higher quality [6]. Moreover, your consumption emerged, in a qualitative approach, as experienced-based product and the goal towards consumption is not functional but symbolic, as a desire for identity and distinction [5]. Also, the Brazilian consumers choice the craft beers because it has an individual quality value and distinct sensory attributes [7].

Polyphenols contribute to bitterness, color, body, and astringency in beer and influences the acceptance of beverages [8]. Beer polyphenols are from barley malt [9] and hop [8] and its content depends on the type of beer and the quantity of hops added during its production, besides the brewing process and fermentation, when some polyphenols chemical changes can occur [9]. Almost 67 different polyphenols were detected in beers, both from barley and hop [10]. Three polyphenol groups (flavan-3-ol, flavonols and phenolic acids) are found in beers and contribute to its flavor, aroma and chemical stability [10]. The more abundant phenolic acid was ferulic acid, founded in

different beer styles, mainly in Pilsen and Weiss [11]. Polyphenols have a key impact in sensory quality of beers, because a higher number of polyphenols leads to a better aroma and flavor of the final product [12]. Some polyphenols act as antioxidants and prevent the oxidative degradation of beers, in addition to providing potential effect on human health, inhibiting mutagenic and carcinogenic agents [8].

In the present study, the relation between polyphenols and bitterness of main different styles of craft beers brewed in Southern Brazilian, and the preference of consumer´s were analyzed. In addition, each style of craft beers has been characterized according its chemical composition, polyphenol content and sensory attributes. As far as we know, few researches have been conducted with the sensorial description and composition of Brazilian artisanal beer styles, evidencing the importance of this work.

2. Material and Methods

2.1. Craft beers and styles

Six different styles of beer were used: Standard American Lager (SAL), Classic American Pilsner (CAP), Weissbier (WSB), American Indian Pale Ale (IPA), Irish Red Ale (IRA) and Robust Porter (RPO). The Table 1 show the craft beer characteristics and packaging specifications. These styles were selected so that each specific beer showed different levels of color, bitterness and ethanol content. All beer samples styles were defined according sensory characteristics and brewing process determinate by Beer Judge Certification Program [13]. The beer samples were purchased from market and were brewed in different localities of Rio Grande do Sul State, in Southern of Brazil (Table 1).

2.2. Craft beers chemical composition

For all beer parameters analyzed, the samples were de carbonated in an ultrasonic bath (Ultra Sonic Cleaner, Unique, São Paulo, Brazil) (30 minutes and at 80 kHz) until the foam disappeared, as indication that the beer did not contained CO_2 [14]. The turbidity was measured in a turbidity meter (TU-2016, Lutron Eletronic, Taipei, Taiwan) and expressed in NTU (Nefelometric Turbidity Units). The pH was directly

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101 measured using a calibrated pHmeter (AZ 86505, AZ Instruments, Taichung City,
102 Taiwan). The total solids were measured by refractometric method using a refractometer
103 (Fisher Scientific, Waltham, MA, EUA) and expressed in °Brix.

104

105 **Table 1:** Characteristics of each craft beer samples regarding your production and packing type. Standard
106 American Lager (SAL), Classic American Pilsner (CAP), Weissbier (WSB), American Indian Pale Ale
107 (IPA), Irish Red Ale (IRA) and Robust Porter (RPO).

Beer samples	Type	Beer color	Packing	Packing volume (mL)	Production city	Purchase place
CAP	Lager	Yellow	Bottle	1,000	Porto Alegre	Specialty store
SAL	Lager	Yellow	Can	473	Caxias do Sul	Supermarket
WSB	Lager	Yellow	Bottle	1,000	Porto Alegre	Specialty store
IPA	Lager	Red	Bottle	500	Campo Bom	Specialty store
IRA	Lager	Red	Bottle	600	Porto Alegre	Specialty store
POR	Ale	Brown	Bottle	600	Gramado	Specialty store

108

109

110 Dry extract was determinate using an aliquot of 25 mL into metallic capsules
111 (weighted before), evaporated in water bath for 30 minutes, approximately, and
112 expressed in g/L. The acidity was measured by titration with a 0.1 M NaOH solution in
113 the presence of phenolphthalein as the indicator, until the appearance of pale pink color
114 that should persist for 1 min. The content of reducing sugar was measured using the 3,5-
115 dinitrosalicylic acid method [15]. All procedures were realized in triplicate and samples
116 were collected from the same production lot.

117

118 **2.3. Beer color**

119 The color of craft beers was determinate by colorimetric method [16, 17]. The
120 beer samples color was determinate by HunterLAB software and a colorimeter

(UltraScan PRO, Hunterlab, Reston, VA, USA) using D65 iluminating standard source calibrated in ultraviolet region. Aliquot of 2 mL of each craft beer was placed in a glass cell with 2 mm of tickness. The parameters analyzed was luminosity (L^*), a^* (green to negative value and red to positive value), b^* (bleu to negative value and yellow to positive value), Chroma (C^*) that indicate the color purity and the angle measurement (h^*) that show the hue of samples color. The C^* was calculated by the equation, $C^* = (a^{*2} + b^{*2})1/2)$; the h^* was measured by the equation: $h^* = tg^{-1}(b^*/a^*)$. Moreover, the absorbance of beer was measured at a wavelength of 430nm in a 10 mm cuvette and the color in EBC (European Brewing Convention) units was obtained by multiplying the absorbance by a given factor [14].

2.4. Polyphenols and antioxidant analysis

The total phenolic content was determined using the Folin-Ciocalteu method [18]. Briefly, in 500 µL of beer samples or standard solutions, 2.5 mL of 0.2 M Folin-Ciocalteau reagent (Sigma-Aldrich, St Louis, MO, USA) were added. The solution was homogenized and equilibrated for 6 min. Then, 2 mL of sodium carbonate (Sigma-Aldrich) solution (75 g/L) were added and mixed. After incubation (2 h) in dark at room temperature, the absorbance was measured at 760 nm. The phenolic content was calculated from the calibration curve of gallic acid (Sigma-Aldrich) standard solutions and expressed as millimoles of Gallic Acid Equivalent (GAE) per mL of craft beers. All determinations were carried out in triplicate.

The antioxidant activity was determinate by DPPH radical-scavenging activity [19]. A 0.1 mL aliquot of methanolic extract was added to 3.9 mL of a 6×10^{-5} mol/L DPPH radical (2,2-diphenyl-1-picrylhydrazyl) (Sigma-Aldrich) in methanol. After 60 minutes, the absorbance of the sample was measured at 515 nm. The decrease of absorbance was determined at 0 min, 1 min and every 15 min until the reaction reached a plateau. The DPPH radical scavenging activity (%) of samples and Trolox standard (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) (Sigma-Aldrich) was calculated as follows:

$$\text{DPPH radical scavenging activity (\%)} = [1 - A_{sample} / A_{control}] \times 100$$

Where, A_{sample} is the absorbance of 100 µL sample + 3.9 mL of DPPH solution and $A_{control}$ is the absorbance of 200 µL 50% methanol + 3.9 mL DPPH solution.

The standard curve was plotted by the Trolox concentration and DPPH radical scavenging activity. Results of DPPH radical-scavenging activity was expressed as µmol of Trolox per mL of beer.

2.5. Determination of bitterness

Craft beers samples were decarbonated and bitter substances were extracted with iso-octane [14]. A sample of 10 mL was mixed with 1mL of hydrochloric acid and 20 mL iso-octane. After, the sample was agitated for 5 min at room temperature and then centrifuged for 15 min at 4000 rpm. The iso-octane phase was decanted and drained carefully to avoid emulsion involvement. The sample tube was covered and left to stand in the dark for at least 30 min before measuring the absorption at 275nm in a 10mm quartz cuvette against pure iso-octane as a reference. Average values of three determinations were used for data analysis; results were expressed as IBU (International Bittering Units).

2.5. Sensory analysis of craft beers

Ethical approval for the sensory tests of this investigation was obtained from the University of Vale do Rio dos Sinos Committee (number 1.247.636) and all participants gave written informed consent to participate in the study.

Two different sensory tests, the preference-ordering test and the Quantitative Descriptive Analysis (QDA) of each beer style were applied. To preference tests, were used a hedonic panel test composed by 62 panelists not experienced and age range to 20-56 years old. Selection criteria were availability and motivation to participate on all days of the experiments and that panelists were regular beer consumers. The QDA was carried out by an experienced panelist (n = 8) to outline the qualitative aspects of beers.

Initially the participants answered questions about the habits of beer consumption, as the frequency of beer consumption; which type, style and brand consume; factors that influence the consumption (prize, packaging, consume places, etc); which sensory characteristics more appreciate in beers (aroma, flavor, color, taste, foam, etc); food pairing with beers.

The preference was evaluated by preference ordering test [20, 21]. The test was realized in individual cabins under white light, and in each session, the beer samples were served at refrigeration temperature ranging from 6 °C to 8 °C. About 30 mL of each beer was served in glass transparent cups, without prior knowledge regarding the brand of the beer being evaluated. The samples were served randomly at the same time and was requested to the assessors order the least preferred to the most preferred craft beers. The preference tests were carried out in four different sessions with intervals of at least eight hours between sessions to avoid sensory fatigue of the consumers. The results were submitted to Friedman test at a significance level of 5% and, after, was calculated the minimum significant difference value between the scores sum obtained with all analysts.

The flavor attributes of Southern Brazilian craft beers were described using methodology of quantitative descriptive analysis (QDA) [20,21]. Fifteen attributes, derived from literature, panelists perception and from the attribute list used by the “beer taster association” [13] were included in the evaluation process. Seven of them were related to flavor (malty, fruity aroma, floral notes, hoppy, phenolic aroma, smoked and yeast odour); two were visual attributes (foam persistency and color) and five were gustatory traits (overall intensity, sweet, bitter, alcoholic, residual flavor) and one concerned to texture (level of carbonation).

The test was realized by an expert panel (n=8), trained to identify the sensory attributes of craft beers. Commercial beers were used in pre-testing panel-test sessions to let the assessors familiarize with the products under investigation and the terminology related. Those sessions were also used to standardize panel’s attributes definitions according to literature and panelists perception.

The sensory attributes were assessed using an unstructured nine-point scale anchored at the left end with “absent” and at the right end with “high”. The samples were identified with a code of three different random digits, where each panelist

212 received 50 ml of each beer sample, monadic and randomly. In all sensory analysis
213 sessions, the panelists received mineral water and dry unsalted breadsticks for palate
214 cleansing between samples to avoid carry-over effects.

215

216 **2.6. Statistical analysis**

217 One-way Analysis of Variance (ANOVA) was performed to detect
218 statistically significant differences among the beers for the sensory attributes and
219 chemical composition. A Tukey HSD post hoc test was used to identify samples that
220 were significantly different from each other (95% of significance). For ordering
221 preference test, the Friedman test and Table of Newel and MacFarlane was performed
222 (95% of significance). Statistical analysis was done using SPSS Statistics 21 software
223 (SPSS Inc., Chicago, IL, USA). Differences of $p<0.05$ were considered significant.

224 Principal component analysis (PCA) was carried out on panel QDA data to
225 identify the key attributes mostly contributing to the variation in products within the
226 product space. All PCA statistical analyses were performed with the XLSTAT, v2017
227 package (Addinsoft, New York, NY, USA).

228

229 **3. Results**

230 **3.1. Consumers and outlines of beer consumption**

231 The panel was roughly gender-balanced (57.4% females and 42.6% males).
232 The average consumer age was 32.09 ± 10.6 years old and ranged from 20 to 56 years
233 old. Regarding the frequency of beer consumption, 81.5% of panel frequently drink beer
234 every day and occasionally consume per week; also consume both commercial and craft
235 beers brands. In another hand, the craft beers more consumed were local beers, followed
236 by the international brands of craft beers available.

237 Concerning the factors that influence the beer consumption, most panelists
238 choose the beer differential and typical sensory characteristics, the type of serving, the
239 beer label design and the beer style. The second more important factor was the
240 consumption place. The factor with minor importance was the type of packaging. The

more important sensory characteristics appreciated by the survey participants was the flavor, and after the beer fragrance notes. Regarding the preference for some style of beer, the most cited were Pilsen, Weissbier and Indian Pale Ale.

For only eight participants (12.9%) in the survey, the calories contained in beer had relevance and the vast majority of participants usually drink with their friends. When talking about the consumption of beer combined with some type of gastronomic preparation, 24 people (38.7%) reported that they do not care about it and 14 (22.6%) do not usually drink with the food and 24 assessors (38.7%) try to harmonize the drink with the food.

3.2. Craft beer composition and color

The craft beers showed a good acceptance from the panel of non-expert assessors and had good quality parameters. All beers tested showed best quality conditions parameters, according international quality guidance. The Table 2 shows the composition of craft beers. In general, the craft beers had a similar composition in sugars, density, acidity and pH; more differences were observed in turbidity, total solids and dry extract.

The Porter style (RPO) showed a higher turbidity (230 NTU) than the others tested samples. This beer had a great pH value (4.40), more solids (10 % m/v), dry extract (7.47 g/L), acidity (2.19 g acetic acid/L), sugars (2.08 % w/v) and ethanol (7.0 % w/w). In addition, this characteristic has been detected and pointed out by hedonic panel, which describe the beer as turbid and with a dark and intense color, as expected by the analysis of parameters. The SAL exhibited the minor turbidity (1.44 NTU), dry extract (3.84 g/L), solids (5.75 °Brix) and acidity (1.49 g acetic acid/L).

Regarding the color of beers, differences in L^*, a* and b* parameters were found. All samples showed great luminosity, but SAL had higher luminosity than other craft beers analyzed (Table 3). The minor L^* value was detected with Porter (RPO) style, a very turbid beer (Table 2). The L^* value ranged from 14.02 (RPO beer) to 91.65 (SAL beer). The a* value represent the color axis green to red and ranged from -0.49 (SAL) to 33.43 (RPO beer). The positive values indicate a perception of red color due the toasted barley use in craft beer production. To the parameter b*, was verified a

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tendency of yellow color and ranged from 24.03 (RPO sample) to 89.6 (IRA beer). The decrease of b* value of some samples of craft beers lead to a reddish color and with brown trace, in function of a* value of color.

Table 2: Principal quality parameters of each craft beer. Standard American Lager (SAL), Classic American Pilsner (CAP), Weissbier (WSB), American Indian Pale Ale (IPA), Irish Red Ale (IRA) and Robust Porter (RPO). Different letters in the same column indicate significant differences between groups of beers ($p < 0.05$, ANOVA followed by post-tests).

Style/Beer	Turbidity (NTU)	pH	Total solids (°Brix)	Dry extract (g/L)	Acidity (g acetic acid/L)	Density	Sugars (% w/v)	Ethanol (% w/v)
CAP	7.27^{e}	4.24^{c}	6.75^{bc}	4.20^{d}	1.84^{c}	1.0112^{b}	0.9^{de}	5.1^{c}
SAL	1.44^{e}	4.12^{c}	5.75^{c}	3.84^{e}	1.49^{d}	1.0098^{b}	0.93^{cd}	5.0^{c}
IPA	37.77^{b}	4.12^{c}	7^{b}	4.21^{d}	1,97^{b}	1.0084^{b}	0.86^{e}	6.2^{b}
WSB	16.78^{d}	3.88^{d}	7^{b}	4.80^{c}	1.97^{b}	1.0116^{b}	0.95^{c}	5.0^{c}
IRA	29.14^{c}	4.33^{ab}	7.75^{b}	5.36^{b}	1.52^{d}	1.0139^{ab}	1.13^{b}	6.2^{b}
RPO	230^{a}	4.40^{a}	10^{a}	7.47^{a}	2.19^{a}	1.0222^{a}	2.08^{a}	7.0^{a}

Chroma value was positive for all craft beer samples, range from 32.74 (SAL beer) to 94.19 (IRA). The beer IRA show a higher chroma when compared to other samples, representing a beer color with more quality, purity, and intensity. The *h* angle oscillated from -1.556 (SAL) to 1.532 (CAP), indicating a more yellow color of beer samples. The *h* is correlated to a* and b* value and is important to differentiate the color hue from different beer samples. The CAP beer has a more intense and yellow hue from the samples tested (Table 3).

The color expressed in EBC units varied from 7.50 (beer SAL) to 157 (beer RPO). Nevertheless, the beer with higher EBC index (RPO: 157) showed a reduced luminosity (91.65) and the less intense EBC color has more luminosity (14.02).

293 **Table 3**: Color parameters of craft beers. *L** (luminosity), *C** (chroma), *h** (hue) and EBC (European
294 Brewery Convention) units. Different letters in the same column indicate significant differences between
295 groups of beers ($p < 0.05$, ANOVA followed by post-tests).

Style/Beer	*L**	a*	b*	*C**	*h**	EBC units
CAP	87.21^{c}	1.82^{d}	47.39^{c}	47.43^{c}	1.532^{a}	13.37^{d}
SAL	91.65^{a}	-0.49^{f}	32.73^{e}	32.74^{e}	-1.556^{e}	7.50^{e}
IPA	77.12^{d}	12.13^{c}	71.72^{b}	72.74^{b}	1.403^{b}	16.75^{c}
WSB	89.90^{b}	1.01^{e}	40.87^{d}	40.89^{d}	1.546^{a}	9.75^{e}
IRA	62.46^{e}	29.06^{b}	89.60^{a}	94.19^{a}	1.257^{c}	44.75^{b}
RPO	14.02^{f}	33.43^{a}	24.03^{f}	41.17^{d}	0.623^{d}	157.0^{a}

296

297

298 ### 3.3. Bitterness, antioxidant activity and polyphenols

299 The beer polyphenols are an important factor to analyze, as they can improve
300 the quality and acceptance of craft beers. The Table 4 shows the content of polyphenols,
301 antioxidant activity and bitterness of each craft beer sample. The beers with higher level
302 of polyphenols were RPO (1.62 mg EAG/mL), IRA (0.95 mg EAG/mL) and WSB (1.68
303 mg/EAL/mL). The commercial beer showed a polyphenols content reduced (0.35 mg
304 EAG/L), compared with other samples. In Table 4, we can verify that the beers that
305 presented higher content of total polyphenols are the same ones with greater antioxidant
306 activity.

307 The antioxidant activity was maximal (5.58 µmol Trolox/mL) with the
308 Weissbier beer (WSB) using DPPH method. In general, the antioxidant activity of the
309 tested beers varied from1.74 µmol Trolox/mL (SAL) to 5.58 µmol Trolox/mL (WSB).
310 The beer bitterness was maximal in IPA beer (46.15 EBU) and the lowest value of
311 bitterness was 9.52 EBU (CAP) (Table 4). The bitterness value varied from content of
312 bitter compounds in beer and not was verified a direct relation of polyphenols content of
313 beers and the bitterness EBC value.

314

315 **Table 4**: Total polyphenols content, antioxidant activity (DPPH method) and bitterness value of different
316 craft beer. Standard American Lager (SAL), Classic American Pilsner (CAP), Weissbier (WSB),
317 American Indian Pale Ale (IPA), Irish Red Ale (IRA) and Robust Porter (RPO). Different letters in the
318 same column indicate significant differences between groups of beers ($p < 0.05$, ANOVA followed by
319 post-tests).

Style/Beer	Total polyphenols (mg EAG/mL)	DPPH (µmol Trolox/mL)	Bitterness (IBU)
CAP	0.61^{c}	3.24^{b}	9.52^{f}
SAL	0.35^{c}	1.74^{d}	11.57^{e}
IPA	0.8^{b}	2.30^{c}	46.15^{a}
WSB	1.68^{a}	5.58^{a}	12.55^{d}
IRA	0.95^{b}	2.05^{c}	33.45^{b}
RPO	1.62^{a}	3.14^{b}	24.72^{c}

320

321

322 ### 3.4. Sensory analysis of beers

323 For hedonic test of beers, were recruited 62 panelists (57.4% of female) to
324 evaluate six different styles. A portion of 81.5% of assessors consumed beer once a
325 week or more than once a week, both commercial brands and local craft beers.
326 Regarding craft beers consumption, both Brazilian and imported brands are consumed,
327 with no difference in the preference between them.

328 About the factors influencing the beer consumption, the majority chose the
329 beverage differential, such as how it is served, the label and style for example. The
330 second most important factor was the place where drink the beers. The less importance
331 factor was the packaging. According sensory characteristics of craft beers, the most
332 prominent was the taste, followed by aroma. For only eight participants (12.5%) in the
333 survey, the calories contained in beer had relevance. On the other hand, the clear
334 majority of participants usually drink with their friends.

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When talking about the consumption of beer harmonized with some type of gastronomic preparation, 20 people (31.25%) reported that they do not care about it and 14 (21.88%) do not usually drink with the food and only 20 people (31.25%) try to harmonize the drink with the food. Concerning the brewing schools (English, Belgian, German and American), 63% did not know any of them and regarding the preference for some style of beer, the most cited were Pilsen, Weiss and Indian Pale Ale.

Nevertheless, regarding the preference test useful, the less preferred beer was IPA and the most preferred style was Pilsen (CAP). The ordering test was considered significant (95% significance) using the Friedman test and, comparing the samples, there was a significant difference in the preference when comparing the scores between them. Pilsen craft beer (CAP) was more preferred when compared to lager beer (SAL) and the other craft beers Porter (RPO), IPA and Weiss style (WSB). In fact, none of the participants chose CAP beer, as the less preferred of all beer samples. Pilsen (CAP), one of the beers with the lowest amount of polyphenols (0.61 mg EAG/mL) and bitterness (9.52 IBU) had a higher preference comparing to the others. Thus, the increasing of polyphenols level and beers bitterness may lead to a decrease in their preference by the panel test. The IPA beer also showed a more intense bitterness (46.15 IBU), being the factor that contributed to their low preference among beer consumers.

The Figure 1 show the sensory profile of different craft beers style by Quantitative Descriptive Analysis (QDA). This data indicate the differences about the craft beer styles according the sensory attributes defined previously. Aroma attributes, carbonation, hoppy and foam are some important characteristics to evaluate by beer consumers. The Table 5 showed the scores obtained by QDA of craft beers tested and all attributes evaluated.

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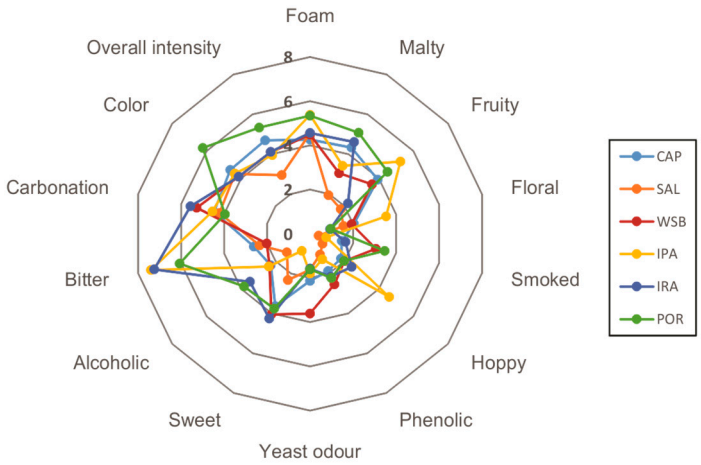

359

360 **Figure 1**: Plots of mean intensity scores for sensory profile of six different craft beers evaluated by
361 quantitative descriptive analysis using a scale of 9 points. Standard American Lager (SAL), Classic
362 American Pilsner (CAP), Weissbier (WSB), American Indian Pale Ale (IPA), Irish Red Ale (IRA) and
363 Robust Porter (RPO).

364

365 The CAP beer show a great sweet flavor score (3.64), but not show great
366 scores of another descriptors (Figure 1, Table 5). The RPO beer exhibited great color
367 (6.23), overall intensity (5.23), foam (5.34), malty (5.08) and smoked (3.48). The more
368 hoppy (4.59) and fruity (5.24) craft beer has IPA. This craft beer has around 2.5 fold
369 more hoppy flavor than CAP beer (1.8), the more preferred beer tested. The bitterer
370 craft beer was IPA (7.40) and IRA (7.25).

371 The consumers are preferred beers with not great polyphenols content, small
372 bitterness (EBU units) and reduced bitter and hoppy character. The Figure 2 show the
373 PCA analysis of beers. Differences in sensory profiles of craft beers by PCA were
374 investigated (Figure 1). This analysis matrix included all sensory attributes evaluated
375 (Figure 1). Two principal components (PCs) were extracted and after analysis of PC1
376 versus PC2 in a bi-plot of samples and the selected variables, one group of samples
377 were discernible (present in the circle). In this PCA plot, PC1 explained 37.94% of total
378 variance and PC2 explained another 29.7%.

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379 **Table 5**: Sensory attributes scores from non-trained assessors (n=62) of different craft beers. Standard
380 American Lager (SAL), Classic American Pilsner (CAP), Weissbier (WSB), American Indian Pale Ale
381 (IPA), Irish Red Ale (IRA) and Robust Porter (RPO). Different letters in the same line indicate significant
382 differences between groups of beers ($p < 0.05$, ANOVA followed by post-tests).

	CAP	SAL	WSB	IPA	IRA	POR
Foam	4.26^{d}	4.54^{bc}	4.49^{c}	5.38^{a}	4.56^{b}	5.34^{a}
Malty	4.33^{c}	1.94^{f}	3.04^{e}	3.41^{d}	4.61^{b}	5.08^{a}
Fruity	3.93^{c}	1.79^{f}	3.59^{d}	5.24^{a}	2.20^{e}	4.50^{b}
Floral	2.04^{b}	1.55^{d}	1.94^{c}	3.54^{a}	0.94^{e}	0.96^{e}
Smoked	1.48^{d}	0.40^{f}	3.06^{b}	0.75^{e}	1.65^{c}	3.48^{a}
Hoppy	1.80^{d}	0.73^{e}	1.99^{c}	4.59^{a}	2.41^{b}	1.98^{c}
Phenolic	1.88^{d}	1.05^{f}	2.55^{a}	1.29^{e}	2.16^{c}	2.23^{b}
Yeast odour	2.14^{b}	1.64^{d}	3.61^{a}	1.80^{c}	1.58^{e}	1.61^{de}
Sweet	3.64^{d}	2.33^{e}	4.05^{b}	0.86^{f}	4.26^{a}	3.76^{c}
Alcoholic	2.29^{d}	1.35^{e}	2.35^{c}	2.39^{c}	3.49^{b}	3.83^{a}
Bitter	2.61^{bc}	2.35^{bc}	2.01^{c}	7.40^{a}	7.25^{a}	6.07^{ab}
Carbonation	4.46^{d}	4.21^{e}	5.28^{b}	4.54^{c}	5.56^{a}	3.96^{f}
Color	4.63^{b}	4.35^{bc}	4.15^{c}	4.36^{bc}	4.14^{c}	6.23^{a}
Overall intensity	4.69^{b}	2.95^{e}	4.09^{c}	3.95^{d}	4.11^{c}	5.33^{a}

383

384 Based on results of PCA and considering all the samples studied beers CAP,
385 IRA and WSB were grouped (Figure 2). The beers IPA, RPO and SAL not clustered
386 together and remained separated in the plots. The group of beers show
387 yeast/fermentation and sweet flavor, and has a great perception of carbonation. In the
388 upper left quadrant, the beer IPA was mainly related to the presence of floral flavor. The
389 IPA style show a more intense perception of floral flavor and hoppy character. The RPO
390 positioned in the upper right quadrant, were more related to the presence of color more
391 intense besides alcoholic, malty, fruity, bitter and overall intensity attributes (Figure 2).

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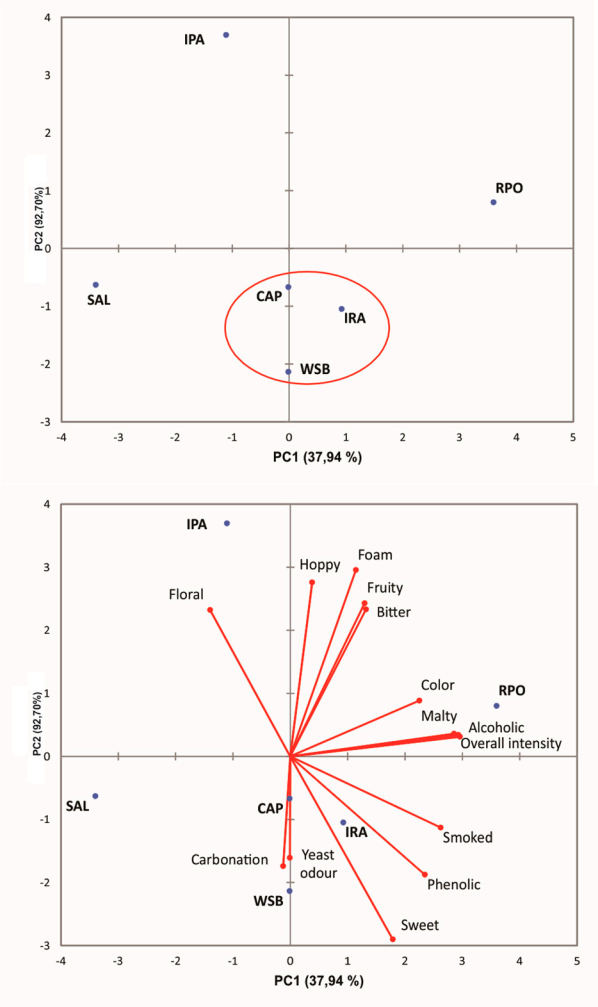

Figure 2: Scatter plots of PCA scores for specific sensory attributes of Southern Brazilian craft beers analyzed in the present study. (PC1 + PC2 explain 67.64% of total matrix variance).Standard American Lager (SAL), Classic American Pilsner (CAP), Weissbier (WSB), American Indian Pale Ale (IPA), Irish Red Ale (IRA) and Robust Porter (RPO).

4. Discussion

Beer is a very complex mixture, and their chemical composition varies considerably [22], as showed in Table 2. In an attempt to bring more light into the differences found in craft beers consumption, the objective of this work was to explore the impact of polyphenol content and bitterness of Southern Brazilian craft beers in the consumer's preference. As, craft beers have different flavors, aromas etc. rather than the usual well-known commercial brands, its preference are increasing among consumers [6].

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These differences of craft beer flavors come from the ingredients used and brewing process [14]. The main ingredients used in beer production are barley, hops, water and yeast [23], where each ingredient plays a crucial role in beer quality and composition. The Porter beer style, for example, is characterized as a substantial, malty dark beer with a complex and flavorful dark malt character [13]. This beer showed big scores of composition parameters than other beers tested in this study. Nevertheless, in general, the tested craft beers were similar in analytical factors than the styles described in BJCP guide [13].

In addition, the craft beers have distinctive and pleasant flavor characteristics to consumers, which easily perceive these attributes [24]. Today, consumer preferences appear to be connected to discovery new beer flavors [6], which can increase the consumption of craft beers. In this way, the Brazilian consumers follows the same trend and search beers with high sensorial quality, differentiated and with characteristic flavor and aroma, as verified in this study. We exposed that the main factor that affect the Brazil beer consumers was the sensory attributes, as pointed by other studies [6, 24, 25]. Additionally, the consumers have a predilection to drink with friends and considers the flavor and fragrances of beer. Furthermore, there were some limitations in this study, mainly concerning the few number of craft beer samples of each style evaluated. Even so, the sensory attributes and craft beer styles selected in this study for their consumer relevance spanned a wide range of beer characteristics.

The most preferred craft beer was the CAP style, which show a main fruity and sweet note, as pointed by survey with tasters. Moreover, studying the consumer behavior can have great value for the beer industry, as it can show how the consumers represent the beer category, the associations linked to them and the proximity across different types of beer [24]. In addition, studies about consumer's preferences can assist brewers in understanding consumers' attitude and in translating consumer needs, wants and expectations into manufacturing designed to produce the best possible, cost-competitive widely accepted product in a relatively short period [26].

The beer is rich in polyphenols, which has acquired from barley and hop, mostly [8]. In our work, polyphenols were found in the six styles of beers evaluated. For example, xanthohumol is the phenol more frequent in hop [27]. Additionally, the Brazilian beers were characterized by high contents of gallic acid and low contents of

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ferulic acid [4]. Both antioxidant activity and total polyphenol content in fourteen varieties of malt produced in China were verified; a positive correlation was found between antioxidant activity and total phenolic content [28]. There were considerable variations in phenolic content and antioxidant activities of beers across different styles. DPPH radical scavenging activity exhibited significant positive correlations with total polyphenols of beers. It is rather difficult to isolate and characterize every compound in beer, and then to evaluate their antioxidant activities due to the diversity and complexity of the natural antioxidant compounds [28].

Investigating the Brazilian beers, the contents of phenolic compounds as well as antioxidant capacity, were like those of beers produced elsewhere in the world [4]. Polyphenols already occur in the early phase of the brewing process, during wort production [10]. As result of this study, we verified that the polyphenols and, mainly the bitterness, have an important relation on preference of different beers by Brazilian consumers. The more preferred beer showed lower bitterness (Table 4, Table 5 and Figure 1) of all styles tested and the second more reduced level of polyphenols (0.61 mg EAG/mL). This same relation of bitterness was verified analyzing the consumer acceptance of craft beers and commercial brands of Brazilian market [29]. Understanding the sensory character of bitterness in beers, and how that relates to their content of polyphenols represents significant value in order to both understand consumer response and optimize production processes [8].

The malt kilning process determines the color parameter and it is quite important as can improve the acceptance of beer [23]. The luminosity (L^* value) also are a great importance, because beers with great L^* value (high luminosity) show a more vivid and intense colour [17]. The lager beers show a great L^* value [17]. Nevertheless, we are demonstrated that the beers more dark and turbid showed big scores of fruity, floral and malty flavor, but a small preference. Beer appearance provides substantial opportunities for product differentiation, and that even beers of the same type have the potential to deliver on rather different usage contexts [30].

The most popular beers style in Brazil is the Germany-style pilsners, very light and clear [2]. This beer style is very common in Brazil market and are a great familiarity to the consumers. Familiar beers would be more often cited as appropriate in most of usage contexts, and that familiar and novel products would be associated to

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different usage contexts [30]. Consumers perceived familiar beers to be appropriate for most uses, more interesting and tasty [30], which may can to an increase the consumer's preference, as verified in this study. The preference order obtained from the study was occasioned by sensory proprieties perceived from the non-trained assessors, because the beer samples was analyzed at the same time, but not assigned to each different style.

From the sensory characterization of Brazilian beer styles was possible to attest that the evaluated consumers could differentiate and prefer the most aromatic and fruity beers. In addition, this distinct character is a choice motivation to buy craft beers instead other beer brands [26]. In addition, a study with Italian consumers, the preference similarly was to beers brewed from moderately kilned/roasted malts, with a milder flavor, and less intense mouthfeel perceptions [25].

Moreover, the IPA was the lower preferred beer, which showed a more level of bitter attribute perception by the panel test. According to international definitions, the IPA style is a hop-forward, bitter, dryish beer, with good drinkability, excessive harshness and heaviness are typically faults and has a strong flavor clashes between the hops and the other specialty ingredients [13]. Furthermore, IPA beer differentiated, by PCA analysis (Figure 2), of other styles because has a characteristic floral note.

Bitterness in particular is a very important quality parameter in beer production [14]. Nearly four consumers out of ten highly appreciated sweet and fruity samples, but they dislike primarily bitterness, burnt and roasted notes, and hoppy resinousness of beer [25]. The bitter foods are generally disliked due to the instinctive rejection of the bitter taste [31]. Variations in liking and willingness to consume bitter foods can be triggered by motivational states in humans [31]. In this study, the beer with reduced bitterness had a higher preference among consumers, showing that bitterness is a key factor and influences beer preference by consumers.

5. Conclusions

The polyphenols content and bitterness determinates the preference of craft beers from Southern Brazilian and consumers can perceive your complex sensory attributes. As supposed, the polyphenols influences the preference of different styles and the beers with minor polyphenols and bitterness (CAP beer) content were preferred

than other craft beer types. The Brazilian craft beers with a lot of antioxidant activity, polyphenols and bitterness was the Porter style (RPO), Red Ale (IRA) and India Pale Ale (IPA). The craft beers showed a complex aromatic notes and flavors, which were described as floral, fruity, yeast and malty. Furthermore, there were some limitations in this study, as it was exploratory, so additional work broadening the craft beers samples size to might be representative of Brazilian craft beers is needed to strengthen our conclusion.

In light of these study findings, it was possible to describe the southern Brazilian craft beers and point the adverse effect of polyphenols and bitterness index in the preference. These results will be important to stimulate the production of more appreciable craft beers by consumers, that found enlarge your drinking experience and hedonic aspects.

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