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Testes Tetraédrico vs. Triangular: Um estudo de caso com refrigerante tipo guaraná

Tetrad vs. triangle test: A case study with Brazilian guarana soft drink

Pruebas Tetraédrica vs. Triangular: Un estudio de caso con gaseosas tipo guaraná

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Kamila Ferreira Chaves
ORCID: https://orcid.org/0000-0001-9865-9011
University of Campinas, Brazil
E-mail: chaves_kamila@yahoo.com.br
Adriana Lucia Wahanik
ORCID: https://orcid.org/0000-0002-8999-558X
University of Campinas, Brazil
E-mail: alwahanikd@gmail.com
Michelly Cristiane Paludo
ORCID: https://orcid.org/0000-0002-8693-7368
University of Campinas, Brazil
E-mail: michellypaludo@hotmail.com
Bianca Iarossi Toledo
ORCID: https://orcid.org/0000-0001-9861-5019
University of Campinas, Brazil
E-mail: biarossitoledo@gmail.com
Alexandre Montagnana Vicente Leme
ORCID: https://orcid.org/0000-0003-3226-1961
University of Campinas, Brazil
E-mail: alexandremvleme@gmail.com
Alessandro Antonio Orelli Junior
ORCID: https://orcid.org/0000-0002-5374-2118
University of Campinas, Brazil
E-mail: orelliaa@hotmail.com
Jorge Herman Behrens
ORCID: https://orcid.org/0000-0002-3952-1722
University of Campinas, Brazil
E-mail: behrens@fea.unicamp.br

Resumo

Testes sensoriais discriminativos tem como objetivo identificar se a diferença entre dois estímulos similares é percebida. Neste estudo nós comparamos a eficácia dos testes Triangular e Tetraédrico na detecção da diferença entre duas amostras de refrigerante do tipo guaraná, através do cálculo da proporção de discriminadores e distância thurstoniana. As amostras avaliadas foram produzidas por diferentes métodos de clarificação do xarope (carvão ativado e coluna de troca iônica). Em cada teste, participaram 99 provadores; o teste Triangular avaliou três amostras e o teste Tetraédrico avaliou quatro amostras, em blocos randomizados. Apenas o teste Tetraédrico foi capaz de detector diferença significativa entre as amostras ($p<0,05$), com uma pequena proporção de discriminadores e distância thurstoniana inferior ao limite de percepção, indicando que o teste Tetraédrico é mais poderoso e sensível que o teste Triangular.

Palavras-chave: Teste discriminativo, Teste Tetraédrico, Teste Triangular, Distância Thurstoniana.

Abstract

Discrimination sensory tests aim to identify if a difference between two similar stimuli is detected. In this study we compared the efficacy of Tetrads and Triangle tests in the difference detection between two samples of guarana soft drink, by means of the calculation of proportion of discriminators and thurstonian distance. Evaluated samples were produced by different syrup clarification methods (activated carbon and ionic exchange column). For each test 99 testers were used; Triangle test evaluated three samples, while Tetrad four samples, in complete randomized blocks. Only Tetrad test was able to detect significant difference between the samples ($p<0.05$), with a low proportion of discriminators and thurstonian

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distance inferior to perception limit, demonstrating that Tetrad test is more powerful and sensible than Triangle test.

Keywords: Discrimination testing, Tetrad test, Triangle test, Thurstonian distance.

Resumen

Las pruebas sensoriales discriminatorias tienen como objetivo identificar si se percibe la diferencia entre dos estímulos similares. En este estudio comparamos la efectividad de las pruebas triangulares y tetraédricas para detectar la diferencia entre dos muestras de gaseosas tipo guaraná, calculando la proporción de discriminadores y la distancia de Thurston. Las muestras evaluadas fueron producidas por diferentes métodos de clarificación del jarabe (columna de intercambio de iones y carbón activado). En cada prueba, participaron 99 catadores; La prueba triangular evaluó tres muestras y la prueba tetraédrica evaluó cuatro muestras, en bloques aleatorizados. Solo la prueba tetraédrica fue capaz de detectar una diferencia significativa entre muestras (p <0.05), con una pequeña proporción de discriminadores y una distancia de Thurston por debajo del límite de percepción, lo que indica que la prueba tetraédrica es más potente y sensible que la prueba triangular.

Palabras clave: Pruebas discriminatorias; Prueba Tetraédrica; Prueba Triangular; Distancia de Thurston.

1. Introdução

Sensory analysis is a crucial stage in the food development cycle as well as in quality control. In this sense, difference testing methods can be effectively used to check for sensory differences between two or more similar stimuli, both in-company and in consumer testing outside the industry environment (Dutcosky, 2013). An important application of difference

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tests is in quality control, with the objective of guaranteeing the homogeneity of products using sensory methods capable of detecting problems that may not be detected through instrumental measures (Muñoz, 2002).

The ability to differentiate two stimuli is the fundamental process underlying sensory-based responses (Lawless & Heymann, 2010). For example, a common question involving production is if a difference between two food samples with the same formulation, but processed at different facilities, might be detected by consumers. In such scenario, trained and experience panels can be used to check for this difference using methods such as the Triangle test (O'Mahony, 1986) or the most recent Tetrad test, which presents four samples to the assessor – instead of three as in the Triangle - , and he must group the samples in pairs based on their similarity (Gridgeman, 1956; Masuoka, Hatjopoulos, & Mahony, 1995). Tetrad and Triangle can be either directional – focusing a specified sensory dimension- or used for general, unspecified differences. Besides, both have the same guessing probability of 1/3, which is the likelihood of success by chance (Lawless & Heymann, 2010). Several studies have proved that Tetrad test is more powerful and sensitivity than Triangle test as it can detect differences with more confidence and fewer assessors (Masuoka, Hatjopoulos, & Mahony, 1995; Delwiche & O'Mahony, 1996; Ennis & Jesionka, 2011; Ennis, 2012; Garcia, Ennis, & Prinyawiwatkul, 2012; Bi & O'Mahony, 2013; Ishii *et al.*, 2014; Ennis & Christensen, 2014b). However, due to the evaluation of four samples, sensory fatigue, adaptation and psychological may occur tetrads test, especially when alcoholic beverages, tobacco and fragrances are tested (Ennis & Christensen, 2014a; Ennis, 2012).

Few studies in the sensory science literature have compared the efficiency of both tests. Garcia *et al.* (2012) performed a high scale study with 404 children comparing the efficiency of Triangle and Tetrad tests for detecting differences between two apple juices.

Authors concluded that Tetrad was more powerful and presented a higher proportion of discriminants than Triangle.

When investigating potential ingredients or process modifications, typical specifications are made: significance level (probability of Type I error - α) at 5%; power at 80% (Type II error at 20%) and level of acceptable difference measures as the proportion of discriminators Pd of 20%. Based on published tables (Schlich, 1993; Lawless & Heymann, 2010), the sample size can also be determinate.

A problem with Pd is that it is method-specific and thus the same sensory difference will correspond to different proportion of discriminator according to the selected difference methods. In this sense, Thurstonian distance δ, a standardized measure of sensory difference, is of interest ASTM E2262−03 (ASTM International, 2014) since it is method-independent and can be easily estimated using sensory data (Ennis, 1993).

In this study we applied Tetrad and Triangle tests to investigate whether a different production process of a carbonated beverage might induce a perceptible sensory difference, a typical case of use of sensory evaluation in quality control. The production of carbonated beverages follows two stages: preparation of simple syrup and preparation of complex syrup. For the simple syrup, water previously treated and sugar are mixed, warmed, filtered and cooled. Afterwards, this simple syrup is mixed with the juice concentrate and further additives (complex syrup), followed by dilution, carbonation and bottling (Barnabé & Venturini Filho, 2010). Sugar and syrup used for beverage production may influence beverage color due to pigments produced during sugar refining and, in turn, color may influence other sensory dimensions such as flavor and taste by means of halo effect (Lawless & Heymann, 2010). In order to inhibit these products from altering the color of the final product, pigments removal is commonly done by means of activated coal or ionic-exchange resins (Rodrigues *et al*., 2000).

For the exposed, we aimed to investigate the efficiency of Triangle and Tetrad tests in detecting sensory differences between two carbonated beverages elaborated using different simple syrup clarification processes, activated carbon and ionic exchange resins.

2. Metodologia

Samples

Guarana soft drink, a very popular and highly consumed carbonated beverage in Brazil, was used as test samples. We used samples of the same brand but processed in two plants under different processes: plant A, which uses activated carbon for sugar syrup clarification, and plant B, which uses the ionic exchange column clarification method.

Activated carbon is a very versatile material used in many industrial applications and particularly for removal of components that may confer undesirable color, flavor and odor to the food products (Qureshi *et al*., 2008). On the other hand, ionic exchange resins in syrup clarification consists in two stages: an acrylic-based column, more hydrophilic and that not form irreversible links with syrup color compounds, and a styrene-based column which removes more compounds due to a higher adsorption capacity. The advantage of the use of these columns compared to the use of activated carbon is the low cost of material regeneration, which enables reuse, and the lower contact time needed (15-30 minutes), compared to activated carbon (2-4 hours) (Konen & Wilson, 1992).

Table 1 presents the physicochemical characteristics of the beverages. Samples were packed in 350 mL aluminum doses.

Table 1. Quality standard analysis of the samples

Parameter	Unit of measurement	Standard Result	Tolerance	Result Plant A	Result Plant B
CO_2 Can	% v/v	3.7	± 0.1	3.6	3.6
Acidity	g citric acid/100 mL	0.106	± 0.003	0.103	0.106
Brix	°Brix	8.5	± 0.1	8.5	8.6
Color	EBC	7	± 0.3	6.9	6.8

Sensory tests

Sensory tests were performed at the Sensory Analysis Laboratory in the School of Food Engineering at the University of Campinas, Brazil. The laboratory is equipped with individual booths with lighting and temperature control.

Differences tests

Before the application of the tests, the number of assessors was calculated using the V-Power software (Ennis & Jesionka, 2011), with a proportion of discriminators (Pd) set at 20%, significance level (α) of 5%, and expected power of 80%. A number of 94 judges was determined for each test. Altogether, 198 individuals were recruited among students and employees of the University of Campinas so that 99 participated in the Triangle test and the other 99 in the Tetrad test.

In both tests 25 mL of the samples were served at 15°C in plastic cups coded with a three-digit random number, on complete balanced blocks. Judges were asked to sip a little amount of water to rinse the palate between samples.

In the Triangle test, assessors received the task: “You have three samples of guarana beverage. Taste them and pick the different one out” (Meilgaard *et al*., 1999). Conversely, in Tetrad the task was: “You have four samples of guarana beverage. Taste them and form two pairs according to the similarity between them” (Dutcosky, 2013).

3. Resultados e Discussão

Statistical Analysis

The proportion of hits (correct answers) were computed and the real proportion of discriminators, the standard error, the upper and lower confidence limits, and the estimate of Thurstonian distance (d’) between samples were calculated using the V-Power software for Microsoft Excel® (Ennis & Jesionka, 2011).

Forty-eight individuals answered the Tetrad test correctly, while thirty-one correct answers were obtained in the Triangle test.

Proportion of discriminators and confidence limits

From the data obtained in each test, it was possible to calculate the proportion of hits (1), proportion of discriminators (2), standard error (3), upper and lower confidence limits (4 and 5), using the following equations (Meilgaard *et al.*, 1999):

$$p_c = \frac{c}{n} \quad (1)$$

$$p_d = 1.5p_c - 0.5 \quad (2)$$

$$s_d = 1.5\sqrt{p_c(1 - p_c)/n} \quad (3)$$

$$Upperconfidencelimit\ (95\%) = p_d + z_\beta s_d \quad (4)$$

$$Lowerconfidencelimit\ (95\%) = p_d - z_\alpha s_d \quad (5)$$

Being:

*c:*number of hits

*n:*total number of answers

p_c:proportion of hits

p_d: proportion of discriminators (Abbot's formula)

s_d:standard error

z_α, z_β: critical values of normal distribution; in the present case, α and β were set at 5 e 80%, respectively, by which z_α=1.645 and z_β=0.842 (Meilgaard *et al.*, 1999).

Starting with the values *c=48* and *n=99* for Tetrad test, and *c=31* and *n=99* for Triangle test, we could calculate statistics related to each test, as shown in Table 3.

Table 3. Sensory tests results

Test	N	c	p_c	P_d	s_d	Lower	Upper	Difference?**	Test

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						confidence limit	confidence limit		power***
Tetraed	99	48	0.4848	0.2273	0.0753	0.1033	0.2907	Yes (p<0.05)	0.911
Triangle	99	31	0.3131	0*	0.0699	0*	0.0589	No (p>0.05)	0.037

* Even thought the calculation result is negative, it is not possible to have a negative discriminators percentage, so it is represented as zero.

**Reference: O'Mahony, 1986.

***Calculated using Software V-Power.

Data shows that Tetrads, which reject the null hypothesis (p<0.05) reached a Pd of 22.73% and with 95% confidence, the proportion of discriminators may vary from at least 10.3% and no more than 29.07%. Conversely, the results of the Triangle test was not significant (p>0.05), the proportion of discriminators was about 0%, due to the low number of hits (31 from 99 answers).

Tetrad test proved to be more sensitive to subtle differences and more powerful than Triangle test, as stated in the literature (Masuoka, Hatjopoulos, & Mahony,1995; Delwiche & O'mahony, 1996; Garcia *et al.*, 2012), with a power (likelihood of finding a true difference) of 91.1% against only 3.7% in Triangle.

Thurstonian distance estimate d'

In order to estimate the Thurstonian distance d', we used the following formula:

$$d' = Z_{hits} - Z_{error} \quad (6)$$

z-value for the hits is given by Lawless and Heymann (2010) using Pd value (Table 2). The Pd for error percent correspond to 5%, with which z_{error}=-1.645.

For Tetrads test, Thurstonian distance was calculated with the following data:

$$d' = -0.74 - (-1.645) = 0.905$$

Table 2. Statistics parameters calculation

	Tetraed	Triangle
P_c	$\frac{48}{99} = 0.4848$	$\frac{31}{99} = 0.3131$
P_d	$1.5 \cdot (0.4848) - 0.5 = 0.2273$	$1.5 \cdot (0.3131) - 0.5 = -0.0303 \cong 0^*$
S_d	$1.5\sqrt{0.4848 \cdot (1 - 0.4848)/99} = 0.0753$	$1.5\sqrt{0.3131 \cdot (1 - 0.3131)/99} = 0.0699$
Upper confidence limit	$0.2273 + \ 0.842 \cdot 0.0753 = 0.2907$	$0^* + \ 0{,}842 \cdot 0{,}0699 = 0{,}0589$
Lower confidence limit	$0.2273 - \ 1.645 \cdot 0.07532 = 0.1033$	$0^* - 1.645 \cdot 0.0699 = -0.1150 \cong 0^*$

*Even thought the calculation result is negative, it is not possible to have a negative discriminators percentage, so it is represented as zero.

However, when calculating the Thurstonian distance for Triangle test, and given a 0% of discriminators, the distance is also zero.

The result obtained for *d´* with Tetrads test is in accordance to the values reported in the literature, as observed in tables that relate Pd and *d´* (Bi & O'Mahony, 2013; Jesionka *et al.*, 2014). The result obtained for Triangle test (*d´=0*) is also in agreement with tables found at the Appendix X1 of ASTM E2262−03 (ASTM International, 2014), where a minimum of 33.33% hits is required to have discrimination between the samples.

According to Jesionka *et al*. (2014), Thurstonian distance is a more accurate measure of discrimination than Pd, because Pd depends on the method and even in tests with the same guessing probability (e.g. Tetrad and Triangle), it may cause error in power calculation as well as in the required number of assessors. Therefore, the authors recommend the use of the thurstonian model, given that it indicates a more significant measure of sensory differences.

Thurstonian distance does not only show if there is difference between the samples, but also if this difference is relevant for consumer (Ennis & Christensen, 2014b). A thurstonian distance *d´* of 1 or higher can be considered a perception limit or threshold, indicating a larger perception difference between the products (O´Mahony & Rousseau, 2002).

4. Conclusão

Tetrad test in the present study detected significant difference between the two samples of guarana soft drink ($p<0.05$) with 91.1% power of finding the difference. On the other hand, Triangle was not able to reject H_0 in a test of very low power (about 3%), even though the guessing probability and the number of assessors were the same in both tests.

The results presented in this study confirm the higher power and sensitivity of the Tetrad compared to Triangle test, to identify sensory differences between two carbonated beverages elaborated using different simple syrup clarification processes.

The authors suggest that further studies are necessary to identify the efficacy of these tests in different products.

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Porcentagem de contribuição de cada autor no manuscrito

Adriana Lucia Wahanik – 15%

Kamila Ferreira Chaves – 15%

Michelly Cristiane Paludo – 15%

Bianca Iarossi Toledo – 15%

Alexandre Montagnana Vicente Leme – 15%

Alessandro Antonio Orelli Junior – 15%

Jorge Herman Behrens – 10%