

LOUISE BERGAMIN ATHAYDE DE SOUZA

**PRODUTOS LÁCTEOS: IOGURTE COM REDUÇÃO DE SACAROSE E
QUALIDADE DO LEITE EM PÓ COMO INGREDIENTE**

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Ciência e Tecnologia de Alimentos, para obtenção do título de *Doctor Scientiae*.

Orientador: Ítalo Tuler Perrone

Coorientadores: Antônio Fernandes de Carvalho
Rodrigo Stephani

**VIÇOSA - MINAS GERAIS
2022**

**Ficha catalográfica elaborada pela Biblioteca Central da Universidade
Federal de Viçosa - Campus Viçosa**

T

S729p
2022

Souza, Louise Bergamin Athayde, 1992-
Produtos lácteos: iogurte com redução de sacarose e
qualidade do leite em pó com ingrediente / Louise Bergamin
Athayde Souza. – Viçosa, MG, 2022.
1 tese eletrônica (44 f.): il. (algumas color.).

Orientador: Ítalo Tuler Perrone.

Tese (doutorado) - Universidade Federal de Viçosa,
Departamento de Tecnologia de Alimentos, 2022.

Inclui bibliografia.

DOI: <https://doi.org/10.47328/ufvbbt.2023.042>

Modo de acesso: World Wide Web.

1. Iogurte - Qualidade. 2. Sacarose. 3. Leite em pó.
4. Gordura. I. Perrone, Ítalo Tuler, 1978-. II. Universidade
Federal de Viçosa. Departamento de Tecnologia de Alimentos.
Programa de Pós-Graduação em Ciência e Tecnologia de
Alimentos. III. Título.

CDD 22. ed. 664.07

LOUISE BERGAMIN ATHAYDE DE SOUZA

**PRODUTOS LÁCTEOS: IOGURTE COM REDUÇÃO DE SACAROSE E
QUALIDADE DO LEITE EM PÓ COMO INGREDIENTE**

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Ciência e Tecnologia de Alimentos, para obtenção do título de *Doctor Scientiae*.

APROVADA: 28 de novembro de 2022.

Assentimento:



Louise Bergamin Athayde de Souza
Autora



Italo Tuler Perrone
Orientador

AGRADECIMENTOS

Primeiramente a Deus, que tudo fez, que tudo É.

Aos meus pais, que se dedicaram para que eu estivesse aqui, obrigada pelo apoio, amor, orações e principalmente por acreditarem em mim.

Ao meu querido orientador Ítalo Tuler Perrone que me auxiliou durante todo esse período sendo sempre solícito, generoso, apoiando minhas escolhas e trazendo calma nos momentos de aflição.

Aos meus coorientadores Antônio Fernandes de Carvalho e Rodrigo Stephani por todo suporte, correções e atenção;

À equipe INOVALEITE por toda ajuda e companheirismo;

Aos meus amigos Gabriel Gama Netto e Vinicius Rodrigues Arruda Pinto que não mediram esforços para me ajudarem;

Aos 351 consumidores que participaram das análises sensoriais;

À Universidade Federal de Viçosa, pela oportunidade de realizar a pós-graduação;

A Todos os professores que compartilharam seus conhecimentos;

Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) pela concessão da bolsa de estudos.

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Código de Financiamento 001.

RESUMO

SOUZA, Louise Bergamin Athayde de, D.Sc., Universidade Federal de Viçosa, novembro de 2022. **Produtos lácteos: Iogurte com redução de sacarose e qualidade do leite em pó como ingrediente.** Orientador: Ítalo Tuler Perrone. Coorientadores: Antônio Fernandes de Carvalho e Rodrigo Stephani.

Os produtos lácteos: iogurte e o leite em pó são amplamente consumidos no Brasil e no mundo e possuem uma grande importância econômica para o país. Aumentar a qualidade desses produtos por meio de alteração de composição, parâmetros de produção, tecnologia empregada e outros é uma maneira dos fabricantes se manterem no mercado, atrair consumidores e atenderem demandas exigidas. No primeiro artigo da tese, o tema abordado é sobre a alteração do teor de açúcar em iogurte. A redução de açúcar, apesar de necessária e eficaz para combater doenças atreladas ao seu excesso, acarreta modificações sensoriais nos alimentos que podem levar a rejeição dos consumidores e prejuízos às indústrias. Estimar o teor máximo de sacarose a ser reduzido sem gerar prejuízos sensoriais é uma alternativa segura para que as indústrias comecem desde já a reduzir esse item dos seus produtos. Neste estudo, a Metodologia dos Limiares Hedônicos (MLH) é utilizada a fim de verificar o teor de sacarose no qual começa a ocorrer comprometimento da aceitação sensorial (Limiar de Aceitação Comprometida - LAC) e o teor de sacarose no qual leva a rejeição sensorial (Limiar de Rejeição Hedônica - LRH) em iogurte de morango, visto que, no Brasil houve um acordo para redução de açúcar em diversos produtos industrializados e o iogurte foi um deles, devendo obter teor máximo de açúcar de 12,8% no produto final. O LAC foi de 9,13% de sacarose e o LRH foi de 6,36% de sacarose, comparados a uma amostra controle contendo 10,64% de sacarose. Ao fornecer aos consumidores a informação que o iogurte possuía mais de 14% de redução de açúcar foi possível aumentar a aceitação sensorial do produto, evidenciando que a informação pode ser utilizada juntamente com a Metodologia dos Limiares Hedônicos para melhorar a experiência hedônica dos consumidores. No segundo artigo da tese, é feita uma revisão bibliográfica sobre a gordura superficial em leite em pó. Quando o leite é desidratado e chega à forma em pó, há uma estabilização dos seus constituintes pela redução da atividade de água e aumenta-se sua vida de prateleira e seu armazenamento é facilitado, gerando, portanto, um produto muito valioso e nutritivo que é muito utilizado como ingrediente na formulação de diversos produtos. Durante as etapas de seu processamento geralmente ocorre uma camada indesejada de gordura sobre a superfície das partículas, sendo composta por frações de gordura livre que leva a efeitos

prejudiciais nas propriedades do pó, incluindo solubilidade reduzida na água, oxidação de lipídios, aumento de viscosidade, perda da qualidade do produto. Conhecer as características dessa gordura e procurar maneiras de reduzi-la se faz necessário para aumentar a qualidade do leite em pó e outros produtos lácteos, que apresentam esse mesmo problema. Essa revisão tem como foco abranger as características do leite em pó, de sua gordura, os relatos sobre esse acúmulo superficial de gordura, além disso indicar algumas alternativas para redução do problema trazido.

Palavras-chave: Redução de açúcar. Iogurte de morango. Limiares Hedônicos. Consumidores de iogurte. Leite em pó. Gordura superficial. Gordura Livre.

ABSTRACT

SOUZA, Louise Bergamin Athayde de, D.Sc., Universidade Federal de Viçosa, November, 2022. **Dairy products: Sucrose reduced yoghurt and quality milk powder as ingredient.** Adviser: Ítalo Tuler Perrone. Co-advisers: Antônio Fernandes de Carvalho and Rodrigo Stephani.

Dairy products: yogurt and powdered milk are widely consumed in Brazil and in the world and have great economic importance for the country. Increasing the quality of these products by changing the composition, production parameters, technology employed and others is a way for manufacturers to remain in the market, attract consumers and meet required demands. The topic of the first manuscript of this thesis regards the modification of sugar concentration in yoghurt fabrication. Sugar level control in fact, is not only necessary and efficient to obstacle health diseases related to its excessive consumption, but it is also deeply interconnected to sensorial and technological modifications which can impact consumer acceptance and brand consideration. In this context, the estimation of the maximum level of sucrose reduction that doesn't impact sensorial properties can be considered as a good starting strategy for diary companies to control its levels into their final products. Brazil has recently agreed to put an effort in sugar reduction in many processed foods such as yoghurt, in which maximum concentration of sugar has been fixed to 12,8%. In this study regarding strawberry yoghurts fabrication, hedonic threshold methodology (HTM) was employed to evaluate the minimum sucrose level that doesn't compromise product acceptance (Compromised acceptance threshold – CAT), as well as the level responsible for sensory rejection (hedonic rejection threshold – HRT). It was discovered that CAT and HRT values were respectively of 9,13% and 6,36% when compared to a product reference of 10,64% of sucrose. Moreover, the information that the strawberry yoghurt has been manufactured with 14% less of sugar allowed to further increase sensorial acceptance of the product, highlighting that such claim could be employed synergistically with the hedonic threshold methodology (HTM) to improve the hedonic experience of the consumers. In the second manuscript of the thesis, a bibliographic review on superficial fat content in milk powder is discussed. When milk is subjected to a flow of dry and hot air is dehydrated to a powder state. The reduction of its water activity allows an increased stabilization of its constituents, producing a valuable and nutritive product characterized by higher shelf life and facilitated storage which is largely employed as ingredient in many food products formulations. However, on the different stages of its production, an undesired free fat layer may migrate to the surface of the powder and may be responsible for quality reduction of

the product, causing defects including lower power solubility, rehydration, lipid oxidation and increased viscosity among the others. It is thus necessary to comprehend and evaluate different strategies to reduce the presence of this free fat layer and control the overall quality of milk powder as well as other milk products which may be affected by the same problem. This review focuses on the characteristics of milk powder, on its fat content and on the problem related to its surface migration. At the same time, some strategies to retain this defect are presented and discuss.

Keywords: Sugar content reduction. Strawberry yoghurt. Hedonic thresholds. Yoghurt consumers. Milk powder. Superficial fat layer. Free fat content.

SUMÁRIO

1. INTRODUÇÃO GERAL	9
2. CAPÍTULO 1	15
Low-sugar strawberry yogurt: Hedonic thresholds and expectations.....	15
3. CAPÍTULO 2	31
Gordura Superficial em leite em pó	31
4. CONCLUSÕES GERAIS.....	43

1. INTRODUÇÃO GERAL

Os produtos lácteos iogurte e o leite em pó são amplamente consumidos no Brasil e no mundo e possuem uma grande importância econômica para o país. Aumentar a qualidade desses produtos por meio de alteração de composição, parâmetros de produção, tecnologia empregada e outros é uma maneira dos fabricantes se manterem no mercado, atrair consumidores e atenderem demandas exigidas. Neste estudo, por meio de dois artigos, será abordada a demanda de alteração para os produtos lácteos iogurte e o leite em pó.

No primeiro artigo da tese será abordado a redução de açúcar em iogurte. A demanda por essa modificação vem de um acordo assinado no Brasil entre o Ministério da Saúde e as indústrias de alimentos para a redução de mais de 144 mil toneladas de açúcares em produtos industrializados (Brasil, 2018a). Tal acordo tem como objetivo reduzir a ingestão de açúcar pelos brasileiros, visto que, esse consumo já ultrapassa 50% a quantidade recomendada pela Organização Mundial da Saúde (OMS) e vem corroborando para o aumento da incidência de doenças como diabetes, obesidade, doenças cardiovasculares, cáries e outras (Organização Mundial da Saúde, 2015). Para o iogurte foi estipulado, por meio deste acordo, uma redução que gere um produto final com teor máximo de 12,8% de açúcar total (Brasil, 2018), porém um dos grandes desafios ao reduzir o açúcar é manter a qualidade sensorial do produto, já que o açúcar impacta diretamente a percepção do gosto doce (Markey, Lovegrove & Methven, 2015) e no iogurte a doçura é um dos fatores mais relevantes para sua aceitação sensorial. (Bayarri, Carbonell, Barrios, & Costell, 2011; Thompson, Lopetcharat, & Drake, 2007; Routray & Mishra, 2011).

Nesse contexto, uma metodologia de resultado rápido e que se mostrou eficaz na redução de sacarose em alimentos foi a Metodologia dos Limiares Hedônicos (MLH) que é capaz de estabelecer uma relação direta entre a aceitação sensorial de um produto e variação de um estímulo específico, auxiliando dessa forma na redução de açúcar em até certo nível sem prejudicar a aceitação sensorial do produto (Lima Filho *et al.*, 2015). A MLH permite a determinação do Limiar de Aceitação Comprometida (LAC) - que indica a intensidade de estímulo no qual a aceitação sensorial do produto começa a ser significativamente menor em relação à uma amostra controle - e o Limiar de Rejeição Hedônica (LRH) - que se refere à intensidade de estímulo no qual começa a ocorrer rejeição sensorial do produto, indicando a transição entre aceitação e rejeição sensorial - (Lima Filho *et al.*, 2015).

Juntamente com a MLH a inclusão de informações nutricionais nas embalagens pode possibilitar escolhas alimentares mais saudáveis (Grimes, Riddell, & Nowson, 2009; Grunert & Wills, 2007; Lytton, 2010; Kim, Nayga, & Capps, 2020; Shangguan *et al.*, 2019), pois apesar de as percepções dos consumidores de iogurte serem impulsionadas principalmente por sua aceitação hedônica o conteúdo nutricional e as propriedades funcionais dessas bebidas também influenciam a escolha do consumidor (Ares, Giménez & Gámbaro, 2008; Johansen, Næs, Øyaas, & Hersleth, 2010).

Em 2020, a ANVISA publicou a RDC Nº 429, uma nova regulamentação sobre a rotulagem nutricional dos alimentos embalados que entrou em vigor dia 09 de outubro de 2022 essa normativa propõe facilitar a compreensão das principais propriedades nutricionais dos alimentos, reduzir as situações que geram engano quanto à composição nutricional, facilitar a comparação nutricional entre os alimentos, aprimorar a precisão dos valores nutricionais declarados e ampliar a abrangência das informações nutricionais em alimentos (Brasil, 2018b; ANVISA 2020). Uma das mudanças inovadoras propostas é a adoção de um modelo de rotulagem frontal, em formato de lupa, que tem por objetivo fornecer uma informação simplificada e padronizada no painel principal do rótulo do alimento, de fácil identificação e compreensão pelo consumidor, que indicará se o alimento tem alta concentração de nutrientes de preocupação à saúde humana (ANVISA, 2019ab). Presume-se que com a implementação dessa nova diretriz o consumo de alimentos ricos em nutrientes potencialmente prejudiciais a saúde caia drasticamente, ao passo que alimentos reduzidos ou isentos em açúcares e sódio, como iogurtes com redução de sacarose, tenham cada vez mais visibilidade no mercado (ANVISA, 2019ab).

O objetivo do primeiro artigo foi usar a Metodologia dos Limiares Hedônicos para reduzir o teor de sacarose em iogurte de morango sem comprometer a aceitabilidade sensorial ou causar rejeição sensorial e também avaliar as expectativas dos consumidores, comparando a aceitabilidade sensorial das amostras em testes cegos e informados, para verificar se os níveis de aceitação para uma amostra comprometida (CAT) aumentariam ou diminuiriam quando a informação de teor reduzido de açúcar fosse indicada no rótulo do produto. Por fim, verificar se por meio dessas metodologias seria possível produzir um iogurte sensorialmente aceito que atendesse aos novos requisitos nacionais de teor de açúcar.

No segundo artigo da tese, aborda-se o tema de acúmulo de gordura superficial em leite em pó, que é um defeito ocasionado durante sua produção e maneiras de evita-lo ou reduzi-lo

é uma demanda crescente. O leite em pó é um produto lácteo com longa vida útil (18 a 24 meses), produzido principalmente a partir de concentrado de leite por secagem por pulverização. Na indústria alimentícia, a forma desidratada é preferida devido à sua facilidade de transporte, processamento e uso em formulações de alimentos. É um alimento muito valioso e nutritivo, que pode ser usado como ingrediente na formulação de uma gama enorme de produtos, incluindo produtos de confeitaria, molhos, massas e até produtos farmacêuticos.

Para uma adequada reconstituição do leite em pó é necessário que o produto possua as características de: molhabilidade; dispersibilidade; solubilidade e penetrabilidade, que dependem de diversos fatores, entre eles as características da superfície da partícula (Carvalho *et al.*, 2020). Ocorre que durante as etapas de processamento acumula-se uma camada indesejada de gordura na superfície das partículas, onde parte dessa gordura encontra-se na forma livre tornando as partículas hidrofóbicas, e dessa maneira, dificultando a hidratação do pó. Além disso, a gordura livre na superfície é um fácil alvo para a oxidação, podendo levar o produto a rancidez hidrolítica, aumento de viscosidade, redução das características de reconstituição (molhabilidade, penetrabilidade, dispersibilidade e solubilidade) e perda de qualidade do produto, dentre outros (Pisecky, 2012; Veja & Roos, 2006; Kim *et al.*, 2005a; Kim *et al.*, 2005b; Nijdam & Langrish, 2006). Isso pode significar uma qualidade de produto deteriorada para o usuário final e uma redução na eficiência durante a fabricação devido à perda significativa do produto. Maneiras de fazer com que essa gordura esteja protegida, encapsulada seria uma alternativa para maior qualidade do produto final.

O objetivo do segundo artigo foi abranger as características do leite em pó, de sua gordura, os relatos sobre esse acúmulo superficial de gordura, relatar os problemas causados e possíveis alternativas para redução desse acúmulo de gordura na superfície das partículas de leite em pó durante a sua fabricação.

REFERÊNCIAS

ANVISA. (2020). RESOLUÇÃO DE DIRETORIA COLEGIADA - RDC Nº 429, DE 8 DE OUTUBRO DE 2020. Rotulagem nutricional dos alimentos embalados. DOU. Edição: 195, Seção: 1, Página: 106. Órgão: Ministério da Saúde/Agência Nacional de Vigilância Sanitária/Diretoria Colegiada.

ANVISA. (2019a). Modelos De Rotulagem Nutricional Frontal De Alto Conteúdo De Nutrientes Críticos Comparado A Outros Modelos De Rotulagem Frontal Nutricional: Uma Revisão Sistemática. Brasília-DF: Agência Nacional de Vigilância Sanitária: 52 p. 2019a.

ANVISA. (2019b). Relatório de Análise de Impacto Regulatório sobre Rotulagem Nutricional. Brasília-DF: Agência Nacional de Vigilância Sanitária - ANVISA: Gerência Geral de Alimentos.: 167 p. 2019b.

Ares, G., Giménez, A., & Gámbaro, A. (2008). Understanding consumers' perception of conventional and functional yogurts using word association and hard laddering. **Food Quality and Preference**, 19, 636-643.

Bayarri, S., Carbonell, I., Barrios, E. X., & Costell E. (2011). Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. **International Dairy Journal**, 21, 111-118.

Brasil. (2018). Ministério da Saúde. **Termo de compromisso para o estabelecimento de metas nacionais para a redução do teor de açúcares em alimentos industrializados no Brasil**. Available at:<http://portalarquivos2.saude.gov.br/images/pdf/2018/novembro/26/termo-de-compromisso-reducao-acucar.pdf> Accessed 20 August 2022.

Brasil (2018b). Termo de compromisso para o estabelecimento de metas nacionais para a redução do teor de açúcares em alimentos industrializados no Brasil. 2018.: Ministério da Saúde: 7 p. 2018b.

Carvalho *et al.* (2020). Química e tecnologia do soro de leite. 1ª ed. **Innovite**, p.173.

Civille, G. V., & Oftedal, K. N. (2012). Sensory evaluation techniques—Make “good for you” taste “good”. **Physiology & Behavior**, 107(4), 598-605.

Er, B., Sert, D., & Mercan, E. (2019). Production of skim milk powder by spray-drying from transglutaminase treated milk concentrates: Effects on physicochemical, powder flow, thermal and microstructural characteristics. **International Dairy Journal**, 99, 104544.

Grimes, C. A., Riddell, L. J., & Nowson, C. A. (2009). Consumer knowledge and attitudes to salt intake and labelled salt information. **Appetite**, 53, 189-194.

Grunert, K. G., & Wills, J. M. (2007). A review of European research on consumer response to nutrition information on food labels. **Journal of Public Health**, 15, 385-399.

Johansen, S. B., Næs, T., Øyaas, J., & Hersleth, M. (2010). Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. **Food Quality and Preference**, 21, 13-21.

Kim, E. H.; Dong, X., & Pearce, D.(2005a) Melting characteristics of fat present on the surface of industrial spray-dried dairy powders. **Colloids and Surfaces B: Biointerfaces** v. 42, p. 1-8.

Kim, E. H.; Dong, X., & Pearce, D. (2005b) Effect of surface composition on the flowability of industrial spray-dried dairy powders. **Colloids and Surfaces B: Biointerfaces**, v. 46, n. 3, p. 182-187.

Kim, S. Y., Nayga, R. M., & Capps, O. (2020). The effect of food label use on nutrient intakes: An endogenous switching regression analysis. **Journal of Agricultural and Resource Economics**, 25, 215-231.

Lima Filho, T., Minim, V. P. R., Navarro, R. D. C., Della Lucia, S. M., & Minim, L. A. (2015). Methodology for determination of two new sensory thresholds: Compromised acceptance threshold and rejection threshold. **Food Research International**, 76, 561–566

Lytton, T. D. (2010). Signs of change or clash of symbols? FDA regulation of nutrient profile labelling. **Health Matrix Clevel**, 20, 93-144.

Markey, O., Lovegrove, J. A., & Methven, L. (2015). Sensory profiles and consumer acceptability of a range of sugar-reduced products on the UK market. **Food Research International**, 72, 133-139.

Nijdam, J. J. & Langrish, T. A. G. (2006) The effect of surface composition on the functional properties of milk powders. **Journal of Food Engineering**, v. 77, n. 4, p. 919–925.

Organização Mundial de Saúde - OMS (2015). **Guideline: Sugars intake for adults and children**. Geneva. Available at: <http://www.who.int/nutrition/publications/guidelines>. Accessed 25 april 2020.

Pisecky, J. (2012). **Handbook of Milk Powder Manufacture**, second ed. GEA Process Engineering A/S.

Routray, W., & Mishra, H. N. (2011). Scientific and technical aspects of yogurt aroma and taste: A review. *Comprehensive Reviews in Food Science and Food Safety*, 10, 208-220.

Shangguan, S., Afshin, A., Shulkin, M., Ma, W., Marsden, D., Smith, J., Saheb-Kashaf, M., Shi, P., Micha, R., Imamura, F., & Mozaffarian, D. (2019). A Meta-Analysis of Food Labeling Effects on Consumer Diet Behaviors and Industry Practices. *American Journal of Preventive Medicine*, 56, 300-314.

Thompson, J. L., Lopetcharat, K., & Drake, M. A. (2007). Preferences for commercial strawberry drinkable yogurts among African American, Caucasian, and Hispanic consumers in the United States. *Journal of Dairy Science*, 90, 4974-4987.

Vega, C., & Roos, Y. H. (2006). Invited Review: Spray-Dried Dairy and Dairy-Like Emulsions-Compositional Considerations. *Journal of Dairy Science*, v. 89, n. 2, p. 383-401.

2. CAPÍTULO 1

Low-sugar strawberry yogurt: Hedonic thresholds and expectations



Received: 29 August 2020 | Revised: 9 January 2021 | Accepted: 12 January 2021

DOI: 10.1111/joss.12643

ORIGINAL ARTICLE

Journal of
Sensory Studies

WILEY

Low-sugar strawberry yogurt: Hedonic thresholds and expectations

Louise Bergamin Athayde de Souza¹ | Vinícius Rodrigues Arruda Pinto¹ |
Luis Gustavo Lima Nascimento¹ | Rodrigo Stephani² |
Antonio Fernandes de Carvalho¹ | Ítalo Tuler Perrone²

¹Departamento de Tecnologia de Alimentos (DTA), Universidade Federal de Viçosa (UFV), Campus Universitário, Viçosa, Minas Gerais, Brazil

²Departamento de Ciências Farmacêuticas, Universidade Federal de Juiz de Fora (UFJF), Rua José Lourenço Kelmer, São Pedro, Juiz de Fora, Minas Gerais, Brazil

Correspondence

Ítalo Tuler Perrone, Departamento de Ciências Farmacêuticas, Universidade Federal de Juiz de Fora (UFJF), Rua José Lourenço Kelmer, São Pedro, Juiz de Fora, CEP 36036-330 Juiz de Fora, MG, Brazil.
Email: italotulerperrone@gmail.com

Funding information

Conselho Nacional de Desenvolvimento Científico e Tecnológico: 315337/2018-4; 311722/2016; Fundação de Amparo à Pesquisa do Estado de Minas Gerais; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

Abstract

Sugar reductions in processed foods can impact a product's sensory aspects and lead to financial losses for the companies that produce them. The aim of the present study was to determine sucrose levels in strawberry yogurt production that would not compromise acceptance (compromised acceptance threshold [CAT]) or result in sensory rejection (hedonic rejection threshold [HRT]). Second, the consumers' expectations were assessed by comparing sensory acceptability of the samples in blind and informed tests to verify the impact of reduced sugar content information on consumer perceptions. The ideal sweetness level of the sampled products was also evaluated. Finally, reduced sugar samples were evaluated with regards to meeting the new national requirements for reduced sucrose yogurts. Samples with a 9.13% sucrose concentration CAT and a 6.36% HRT were obtained when using the hedonic threshold methodology (HTM), from a control sample containing 10.64% sucrose. Over 14% of the sucrose in yogurt can be reduced without altering sensory acceptance, but a 40% or greater reduction in sucrose content may lead to sensory rejection of strawberry yogurt. The present study demonstrated that reductions which meet the required Brazilian standards can be made without affecting sensory acceptance.

Practical Applications

This was the first study to use the HTM to study sucrose reduction in dairy products. The results presented herein could have an important impact on industry, public policy makers, and consumers and may help dairy manufacturers meet established sugar reduction goals without affecting sensory acceptance. The effects are an important contribution to food science even when there are no sugar reduction requirements in play. Companies that have tested the impact of sugar reduction and studied how much sugar can be appropriately removed will be ahead of their competitors when these dietary requirements are implemented.

1 | INTRODUCTION

Excessive sugar consumption is a public health issue associated with several comorbidities including obesity, hypertension, Type 2 diabetes,

cardiovascular diseases and other noncommunicable diseases (Wang, Coxson, Shen, Goldman, & Bibbins-Domingo, 2012; WHO, 2015). Effective public policies and strategies aimed at reducing the sugar added to foods, which in turns reduces the overall sugar consumption,

are in high demand (Buckton et al., 2017; Grummon et al., 2019; Hagemann, Siegrist, & Hartmann, 2018; Stacey et al., 2019; Vreman et al., 2017). Over the last decade, the incidence of diabetes has increased by 54% in men and 28.5% in women. Obesity has also risen more than 60% in Brazil. It is estimated that sugar consumption in Brazil is 50% higher than established by the World Health Organization (WHO) guidelines, or the equivalent of an 80 g daily intake of sugar per person. A significant portion of this ingested sugar comes from processed foods (Brasil, 2018). These statistics have led the Brazilian Ministry of Health and the Brazilian Association of Food Industries (ABIA) to sign an accord aimed at reducing over 144 thousand tons of sugar in processed foods. Cookies and dairy products have been targeted for the highest reduction percentages. In the case of yogurt, the goal is to reach a maximum total sugar content of 12.8% in the final product by the end of 2022 (Brasil, 2018). Although yogurt is widely consumed and has many health benefits, yogurt products sweetened with sucrose generally contain high sugar contents and can have negative health impacts (Pohjanheimo & Sandell, 2009).

Reducing sugar in foods is a necessary and effective means of disease control; however, it can negatively impact food quality. The main challenge is product sensory modification (Markey, Lovegrove, & Methven, 2015; Raaij, Hendriksen, & Verhagen, 2009). Regarding strawberry yogurt, the sensory attributes most important to consumers are aroma and taste, including sweetness, which is one of the key factors for acceptance of yogurt and similar products (Bayarri, Carbonell, Barrios, & Costell, 2011; Routray & Mishra, 2011; Thompson, Lopetcharat, & Drake, 2007). Reducing the sugar content without sacrificing taste or negatively affecting sales has proven to be a challenge, and the reduction in sweetness can cause major financial losses in the dairy industry (Biguzzi, Schlich, & Lange, 2014).

One means of reducing the sugar content in processed foods has been the use of low-calorie sweeteners. It is widely accepted that aspartame, neotame, stevia, and sweetener blends play an important role in the sensory aspects of acceptance and consequently affect the consumers' hedonic response to yogurts (Hernández-Morales, Hernández-Montes, & Villegas-de Gante, 2007; Kalicka, Znamirska, Buniowska, Esteve Más, & Canoves, 2017; King, Arents, & Duineveld, 2003; King, Lawler, & Adams, 2005; Miele et al., 2017; Pinheiro, Oliveira, Penna, & Tamime, 2005; Tan, Wee, Tomic, & Forde, 2020). These substances deliver high levels of sweetness without increasing the caloric intake (Carocho, Morales, & Ferreira, 2017). However, through sensory analyses such as temporal dominance of sensations (Wagoner, McCain, Foegeding, & Drake, 2018) and descriptive analyses (Cadena, Cruz, Faria, & Bolini, 2012; Keefer, Nishku, Gerard, & Drake, 2020), it has already been found that the use of non-nutritive sweeteners can alter the sensory profile in dairy products. This includes modifying the texture of whey protein-based products (Wagoner et al., 2018), causing bitter and metallic flavors in protein bars (Keefer et al., 2020) and adding bitter taste and altering the creaminess intensity in ice cream (Cadena et al., 2012). Some consumers have also reported a negative perception of alternative sweeteners because they confer a residual artificial sweetness that may also be metallic and/or bitter (Chattopadhyay, Raychaudhuri, &

Chakraborty, 2014; Schiffman, Booth, Losee, Pecore, & Warwick, 1995; Shim et al., 2011); it is believed that this is characterized by the taste resulting from the sweetener's ability to interact with multiple binding sites within the taste receptor (Allen, McGeary, & Hayes, 2013), providing different residual sensations on the palate.

The simple reduction of sugar in yogurt products is a viable alternative, since it does not call for replacing it with other ingredients. The reduction can be carried out gradually, reducing sugar in small percentages over time, thus making them imperceptible to consumers (MacGregor & Hashem, 2014; Oliveira, Galhardo, Ares, Cunha, & Deliza, 2018). However, this gradual reduction method requires a long time period before a significant reduction in sugar content is reached, as well as a commitment to a gradual reduction strategy; regular use of new reduced-sugar products is also important to obtain success in "healthier" innovations (Ma, He, Yin, Hashem, & McGregor, 2016). The hedonic threshold methodology (HTM) can generate faster results and has already been proven effective in reducing sucrose in grape nectar and sodium in beef hamburger (Lima Filho et al., 2019; Lima Filho, Minim, Navarro, Della Lucia, & Minim, 2015). The HTM establishes a direct relationship between a product's sensory acceptance variations with regards to a specific stimulus and then quantifies the magnitude of the differences between the samples (Lima Filho et al., 2015; Lima Filho et al., 2017; Lima Filho et al., 2018; Lima Filho et al., 2019). Unlike other threshold methods (e.g., difference threshold, detection threshold), the HTM does not infer that variability in the perceived intensity of certain attributes results in an alteration of food sensory acceptance without further investigating the effects on the sample's sensory acceptance (Boring, 1946). The HTM includes two hedonic thresholds: the compromised acceptance threshold (CAT) and the hedonic rejection threshold (HRT). The former indicates the intensity of the sample stimulus, where sensory acceptance of the product starts to significantly decrease. The latter refers to the intensity of the sample stimulus where product sensory rejection begins to occur, indicating a transition between sensory acceptance and rejection (Lima Filho et al., 2015).

Food industries are often required by health agencies and regulatory measures to reduce ingredients that impact the sensory quality of their products. When these reductions achieve CAT levels, the sensory acceptance levels decrease. Companies should seek extrinsic resources to improve consumer experience and reduce or avoid financial losses. Providing nutritional information can increase the acceptance levels of an otherwise unaccepted sample and even make it as acceptable to consumers as the original product.

Providing information to health-conscious consumers can further the acceptability of low-sugar products (Capacci et al., 2012; Reis, Alcaire, Deliza, & Ares, 2017). Including nutritional information on food packaging has been considered one of the most important public policies for enabling informed, healthy food choices (Grimes, Riddell, & Nowson, 2009; Grunert & Wills, 2007; Kim, Nayga, & Capps, 2020; Lytton, 2010; Shangguan et al., 2019). The perceptions of yogurt consumers are mainly driven by their hedonic acceptance, but the nutritional content and functional properties of these beverages heavily influence consumer choice (Ares, Giménez, & Gámbaro, 2008). It has also been found that strawberry yogurt consumer acceptance levels

tend to increase when consumers are provided with health information (Johansen, Næs, Øyaas, & Hersleth, 2010).

The aim of the present study was to use the HTM to reduce the sucrose content in strawberry yogurt without compromising sensory acceptability or causing sensory rejection. Second, the expectations of consumers were assessed by comparing sensory acceptability of the samples in blind and informed tests to verify whether the acceptance levels for a compromised sample (CAT) would increase or decrease when reduced sugar content information was indicated on the product label. The ideal sweetness level of the sampled products was also evaluated. Finally, the reduced sugar samples were evaluated with regards to meeting the new national requirements for reduced sucrose yogurts, thus providing consumers with new, healthier food options.

2 | MATERIALS AND METHODS

2.1 | Sample preparation

Six strawberry yogurt samples were produced and formulated according to the following sugar/yogurt volume ratios (w/v): 10.64%, 9.64%, 7.64%, 5.64%, 3.64%, and 1.64%. The sample with the highest sucrose content was used as the control sample (10.64%). The protocol for determining the CAT and HRT was conducted in accordance with the procedures proposed by Lima Filho et al. (2015). The control sample must be the most accepted and the stimuli must be in an appropriate range that includes the individual sensitivity of the evaluators and the threshold to be determined. Other samples were referred to as stimulus samples, following an arithmetic reduction in relation to the control (2.00%). Additionally, the 9.64% sample was inserted as the most similar stimulus to the control sample in terms of better acceptance (data not shown). In threshold determination, it is necessary to use a stimulus intensity range that includes the threshold to be determined (Lawless & Heymann, 2010) and use of the 9.64% sample increases the confidence that the calculated thresholds were higher than the chosen lower limit. Only then is it possible to find a wide range of stimulus concentrations where it is possible to obtain the CAT and HRT. In the second step of this experiment, two yogurts with a sugar concentration equal to the control sample (10.64% w/v) and a sample corresponding to the CAT sample (9.13% w/v) were selected in order to verify how far the ideal sweetness is from the compromised sample, and what is the ideal sweetness level of the control sample. Next, consumer expectations were assessed in a three-session acceptance test (A, B, and C). CAT and control samples were evaluated with regards to meeting the new national requirements for reduced sucrose yogurts. The strawberry flavor was selected because it is a familiar flavor that is widely accepted by most yogurt consumers (Pinto et al., 2020).

2.2 | Materials

Pasteurized milk and commercial sugar were purchased from retail brands commonly found in Viçosa, Minas Gerais, Brazil. Milk with a 3.0% fat content was pasteurized. The dairy culture for the

fermentation stage was provided by DSM. It was composed of *Streptococcus salivarius subsp. thermophilus* and *Lactobacillus delbrueckii subsp. bulgaricus* DELVO FRESH YS-131 (DSM, Delft, the Netherlands). Strawberry syrup containing 41% sucrose (w/v) was supplied by AVANTE (Juiz de Fora, Minas Gerais). This value was taken into account when calculating the final sucrose content of the yogurt samples.

2.3 | Sucrose syrup preparation

Sucrose syrup was prepared by dissolving 65% sugar in 35% distilled water. The syrup underwent heat treatment at 90°C for 5 min in an industrial steam cooking pot. The syrup mass was weighed before being added to each sample and it was added only at the end of production.

2.4 | Formulation

A single heat treatment, a single fermentation step, and a single strawberry syrup addition were performed for optimal sample standardization. These three treatments are extremely important in determining the texture, flavor, and aroma of yogurt products (Hutkins, 2006; Labropoulos, Collins, & Stone, 1984; Lee & Lucey, 2003; Parnell-Clunies, Kakuda, deMan, & Cazzola, 1988; Sodini, Lucas, Oliveira, Remeuf, & GCorrieu, 2002) and may impact sample acceptance. Thus, a single fermented base was obtained for all treatments.

Heat treatment was applied to the milk in an industrial steam cooking pot at 90°C for 5 min, then the milk was cooled to 42°C and DELVO FRESH YS-131 was added. The milk was then placed in stainless steel vats set in a water bath at 42°C. The pH was measured over time until it reached 4.6 on a pHmeter (Kasvi pH meter, Curitiba, Brazil). The yogurt was broken up by hand, cooled to 30°C and the strawberry syrup was added according to manufacturer guidelines (4%), which supplied 1.64% (w/v) of sucrose to all samples. During the last step, sucrose syrup was added to the yogurts to complete each formulation. Two yogurt productions campaigns (repetitions) were carried out for both parts of the experiment.

2.5 | Physicochemical analysis

2.5.1 | Centesimal composition

The moisture content was determined using a gravimetric scale, protein levels were determined by the Kjeldahl method, fat was measured using the Gerber method, ash content was determined by muffle incineration at 550°C (AOAC, 2016) and carbohydrates were determined in the yogurt samples as the difference.

2.5.2 | Titratable acidity analysis

Titrate acidity was determined by titration with a NaOH 0.111 M solution, expressed in % lactic acid; and pH measurements were

carried out using a pH meter (Kasvi pH meter, Curitiba, Brazil). The yogurt samples were evaluated after 1, 14, and 28 days (AOAC, 2016).

2.6 | Sensory analysis

This study was approved by the Research Ethics Committee for Human Beings at the Federal University of Viçosa (UFV) (n° 3.924.235). Sensory evaluations were conducted at the UFV Technological Innovation Laboratories, in individual booths under white light. In the first part, the samples were presented in order of decreasing sucrose concentrations between sessions, and the position of the control sample within each pair was randomized. A total of five acceptance test sessions were carried out (Lima Filho et al., 2015). In the second part, the samples were presented monadically and randomized according to a balanced experimental design. Sensory analysis was performed in individual booths with white light and under controlled sample temperatures (7–10°C). Participants tasted samples served in transparent, odorless plastic cups (50 ml) encoded with three random digits, and were instructed to drink the sample (15 ml per sample), followed by water to cleanse their palates between samples. Each participant represented one repetition of the design.

2.6.1 | First part: CAT and HRT

A total of 121 regular yogurt consumers were recruited for a study to determine the hedonic thresholds. The group was composed of 64 women and 57 men with an average age of 23.8 ± 7.4 . Individuals answered recruitment questionnaires with regards to the sensory analysis sessions, and the criteria for selection of the participants were: consume yogurt at least once a month, declare that like the strawberry flavored beverage, have a habit of observing food labels and be at least 18 years old. More details on the participants' characteristics are shown in the Appendix A. At the end of the assessment, individuals were asked to complete the *Health Consciousness Scale* questionnaire approved for the Brazilian population (Dantas, Minim, & Deliza, 2003).

Consumers received two samples, in pairs (control and stimulus samples), for each acceptance test session: a control sample (10.64% sucrose) and a stimulus sample (9.64%—Session 1; 7.64%—Session 2; 5.64%—Session 3; 3.64%—Session 4; 1.64%—Session 5). During the sessions, the stimulus samples were presented in decreasing order of sucrose concentration and the position of the stimulus sample within each pair was randomized. A total of five acceptance test sessions were carried out (Lima Filho et al., 2015). During the sessions, consumers were asked to taste the samples from left to right and rate them on a scale of 1 to 9 (1: extremely dislike; 9: extremely like). After each session, consumers were asked to rinse their mouths with filtered water and wait 5 min before tasting a new pair of samples.

A *t* test was administered for paired samples to determine their CAT thresholds. This test was used to calculate the hedonic result

differences between the control and the stimulus samples for each session. A regression model was adjusted to the experimental data, which included *t* values and the yogurt sucrose content. The model was chosen based on the parameter significance ($p \leq .05$) and the highest coefficient of determination values R^2 ($SQ_{\text{regression}}/SQ_{\text{total}}$). The CAT was calculated using the model equation and corresponded to the point at which the calculated *t* value was equal to the tabulated *t* value. At this point, a significant change in yogurt sensory acceptance occurs as a result of sucrose reduction (Lima Filho et al., 2015).

The HRT refers to the stimulus intensity of a product which reaches a mean hedonic score of 5 on a 9-point hedonic scale. This score refers to the term “indifferent,” and it was chosen because consumer indifference can cause individuals not to purchase a product (Della Lucia, Minim, Silva, Minim, & Cipriano, 2013; Della Lucia, Minim, Silva, Minim, & Cipriano, 2014). A regression model was adjusted to the experimental data to include hedonic scores and the yogurt sucrose concentration to determine the HRT. The model was chosen according to the parameter significance ($p \leq .05$) and the highest coefficient of determination values R^2 ($SQ_{\text{regression}}/SQ_{\text{total}}$). The HRT was calculated using a model equation, where the HRT and sucrose content meet at a point where the mean hedonic score reaches 5. At this point, sensory rejection of the yogurt is observed due to sucrose reduction (Lima Filho et al., 2015).

A graph showing the *t* values of each session (Y1 axis) was constructed using model equations as a function of the sucrose content (X axis) and hedonic scores (Y2 axis). The region where significant sensory acceptance differences occurred between the yogurt samples was shown on the graph by a dashed line and refers to the tabulated *t*-value (1.9799), at a 5% level of significance, for $GL = n - 1$ consumers. The HRT cut-off point was shown as a dashed line on the graph at a hedonic score of 5 (hedonic term “indifferent”).

2.6.2 | Second part: Ideal sweetness determination for the CAT samples and influence of label information on consumer expectations

Ideal sweetness and expectation tests were performed using only the control and CAT samples. The CAT samples were determined in the first experimental stage (determination of hedonic threshold) to represent the stimulus intensity level (sucrose) at which a yogurt sample has a lower acceptance level than the control sample, that is, a sample less accepted than the control sample. The goal here was to understand how consumers evaluated the CAT sample sweetness and how their expectations may affect acceptance levels.

Ideal sweetness determination for the CAT samples

To determine the CAT ideal sweetness, 112 regular yogurt consumers were recruited. The group was composed of 50 women and 62 men, who were on average 23.7 ± 7.2 years old. Next, 118 regular yogurt consumers that included 60 women and 58 men with an average age of 22.6 ± 6.4 were recruited to assess the effect of their expectations on reduced sucrose yogurt. The inclusion criteria were: an interest in

participating in the study, minimum strawberry yogurt consumption of once per month, and age of 18 or older. Participants comprised consumers living in Viçosa city, including university students, professors, and employees.

To determine the ideal sweetness, a questionnaire with seven categories was administered using the JAR scale (Just-about-right-scale). This category scale ranged from “Not sweet at all” to “Much too sweet”. The assessment was both monadic and randomized.

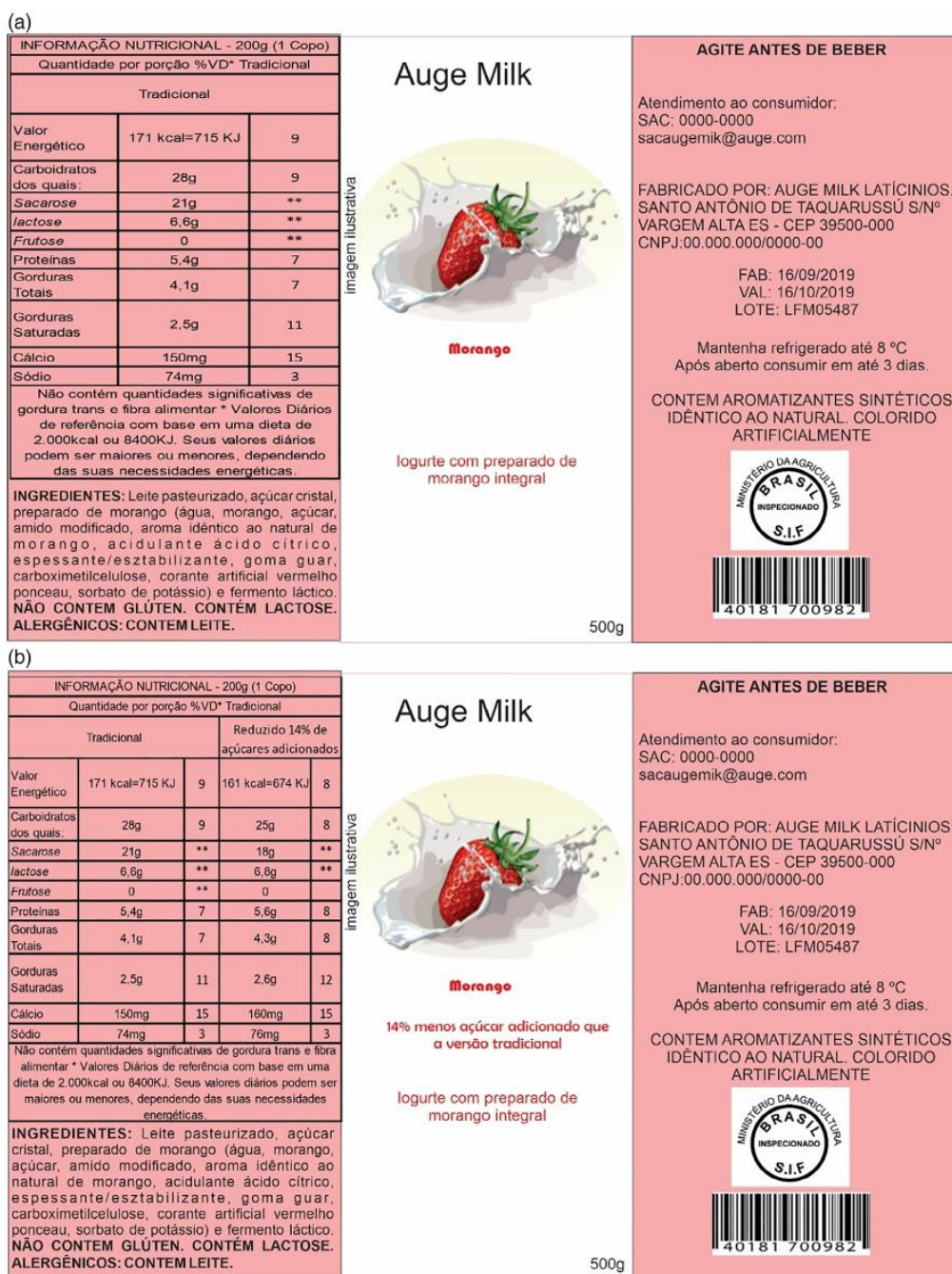


FIGURE 1 (a) Control strawberry yogurt sample label (10.64% sucrose). (b) Compromised acceptance threshold (CAT) strawberry yogurt sample label (9.13% sucrose) with added information “14% less added sugar than traditional yogurt products”

Influence of label information on consumer expectations

Blind and informed tests were carried out to determine whether product labels indicating the reduced sugar content would alter consumer opinion of the CAT yogurt sample (9.13% sucrose). Two strawberry yogurt labels (Figure 1) were printed to include all regulatory nutritional information (Brasil, 2003). The difference between the control sample and the CAT sample was 14.2% sucrose but for practical reasons related to legislation on the label the value presented was 14%. The CAT label read: "14% less added sugar than traditional yogurt." In addition, the nutritional label indicated minor differences from the control sample (10.64% sucrose). The 18- × 10-cm labels were printed by a local printer, made of coated paper, and affixed to 500 ml empty white plastic bottles made of high-density polyethylene (HDPE), then presented to the subjects.

The procedures for the blind, packaging and informed tests are described below:

First session (A): Subjects received control and CAT samples without prior knowledge of formulations and were asked to rate them on a 9-point hedonic scale (1: extremely dislike; 9: extremely like).

Second session (B): Subjects received two yogurt labels (Figure 1a,b) and were asked to rate them and the information they contained on a 9-point hedonic scale.

Third session (C): Subjects were given yogurt samples with corresponding labels. Subjects tasted samples and responded how much they liked or disliked them with prior knowledge of label information.

All samples were served monadically and randomly in Sessions A, B, and C.

2.7 | Statistical analyses

Regression models for each nutritional component (fat, protein, moisture, ash, and carbohydrate) were adjusted for sucrose concentration to evaluate the effect of sucrose content on the yogurt components. The models were chosen based on parameter significance ($p \leq .05$) and higher coefficient of determination values R^2 (SQ_{regression}/SQ_{total}). pH and acidity were also submitted to regression analysis to evaluate the effect of sucrose content over time (data not shown).

T tests were performed and a regression model of the t value was adjusted for sucrose content to determine the CAT sample. To determine the HRT, a regression model of hedonic means was adjusted for sucrose content. The models were chosen based on parameter significance ($p \leq .05$) and higher coefficient of determination values R^2 (SQ_{regression}/SQ_{total}).

An analysis of variance was performed on the data from each of the sessions (A, B, and C) to identify differences between mean hedonic scores of the yogurts (Control and CAT). In order to evaluate the expectations generated by the label and the effect of nutritional information on yogurt acceptance, differences between the hedonic scores for the label test and the blind test (Session B – Session A), and the informed test and blind test (Session C – Session A) were calculated for each yogurt (Control and CAT).

Statistical tests were performed using the SAS software (Statistical Analysis System—SAS), version University Edition.

3 | RESULTS

3.1 | Physicochemical analysis

A centesimal composition analysis was carried out on yogurt samples to ensure that the sucrose content met the limits established by the Ministry of Health and the food manufacturer standards for total sugars in yogurt products (Brasil, 2018). The carbohydrate levels therefore accounted for the highest percentage of the sugar levels. For the purposes of this study, the carbohydrate content is considered the total sugar content, because carbohydrates in yogurt are almost exclusively mono- and disaccharides.

All models were significant ($p < .01$) and established component variations according to the sucrose content (Table 1). The addition of sucrose (sucrose syrup) reduced all component amounts except carbohydrates. The yogurt sample fat content varied from 2.08% to 2.75%, protein content varied from 2.71% to 3.12%, and carbohydrate content varied from 5.40% to 14.24%.

A reduction in fat, protein, moisture, and ash content was expected due to the choice of a single base rather than attempting to standardize dry extracts for all formulations during yogurt production.

The pH and acidity levels (Figure 2a,b)) and regression analysis (data not shown) demonstrated similar behavior for all treatments. Acidity levels increased during 28 days of storage (Figure 2b); pH values decreased but remained within the Brazilian regulatory standards before reaching the expiration date (Brasil, 2007). The fact that all samples obtained similar behavior of these measures (pH and acidity) is very important, since the acidity in fermented dairy products can mask the perception of other attributes related to flavor, including sweetness and consequently the acceptance of the samples, since the acceptability levels of yogurt are primarily a function of sweetness and acidity (Barnes, Harper, Bodyfelt, & McDaniel, 1991a).

3.2 | First part: Hedonic thresholds for sucrose reduction in strawberry yogurt

The paired t test was performed using hedonic means obtained during each session (Table 2). Sensory scores obtained from stimulus samples

TABLE 1 Regression models for fat, protein, moisture, ash and carbohydrates as a function of sucrose content (x), regression coefficients, and significance

Regression models	R^2	p (f)
1) Fat = $-0.07879x + 2.89673$	.9858	<.001**
2) Protein = $-0.04414x + 3.18071$	.9941	<.001**
3) Moisture = $-0.82169 + 89.34246$	.9947	<.001**
4) Ash = $-0.01402 + 0.86253$	.9320	<.001**
5) Carbohydrates = $0.95915x + 3.70941$	.9956	<.001**

**Significant at 1% ($p < .01$).

(10.64% and 9.64%—Session 1, 10.64% and 7.64%—Session 2, 10.64% and 5.64%—Session 3, 10.64% and 3.64%—Session 4, 10.64% and 1.64%—Session 5) decreased as the sessions

progressed, which was expected due to sucrose reduction. A significant difference ($p < .05$) between the samples (control and stimulus sample) was found in the second session, indicating that the control sample was significantly more accepted than the stimulus sample (7.64%), and the CAT was located between the 7.64% sample and the 9.64% sample. For the two data sets (calculated t values and average hedonic scores), the model that showed the best fit was linear, with significant regression coefficients ($p < .05$) and coefficients of determination (r^2) greater than .98 (Table 3). In the Y1 regression model presented in Table 3, when replacing “Y1” with 1.9799 (tabulated t value, $\alpha = .05$; $n = 120$), it is possible to calculate the compromised acceptance threshold (CAT), that is, calculate the sucrose content at which a change in sensory acceptance of strawberry yogurt equivalent to 9.13% sucrose begins to occur. Any sucrose content equal to or less than 9.13% is less accepted than the control sample. In the third session (5.64% sucrose), the hedonic mean was less than 5, indicating that the HRT was between the samples of 5.64% and 7.64%. From equation Y2 (Table 3), it is possible to calculate the hedonic rejection threshold, that is, the sucrose content at which the sensory rejection of yogurt begins to occur. This is done by substituting “Y2” for 5. The value found for the HRT was 6.36% sucrose, indicating that sucrose contents equal to or less than 6.36% would lead to sensory rejection of the product.

As shown in Figure 3, yogurts with sucrose contents greater than 9.13% are below the dashed line of $t = 1.97$ (Equation (Y1)), indicating that these samples will have the same sensory response as the control sample; in contrast, samples and yogurts with sucrose contents greater than 6.36% are above the dashed line representing the hedonic mean 5 (Equation (Y2)) and represent samples which are sensorially accepted.

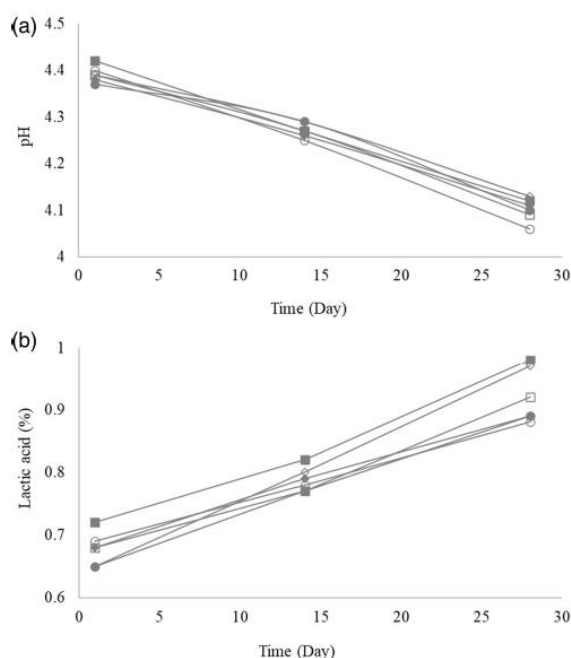


FIGURE 2 (a) Yogurt pH for different sucrose levels over time (b) percentage of lactic acid in yogurts over time. (■) 10.64% sucrose, (□) 9.64% sucrose, (◆) 7.64% sucrose, (◇) 5.64% sucrose, (●) 3.64% sucrose, (○) 1.64% sucrose

TABLE 2 Hedonic scores for each session and significance ($p \leq .01$)

Session	Hedonic means ($n = 121$)		T value	p value
1	10.64% sucrose	9.64% sucrose	0.4	.8241267 ^a
	6.7 ± 1.62	6.6 ± 1.45		
2	10.64% sucrose	7.64% sucrose	6.1	<.001 ^{**}
	6.9 ± 1.61	5.9 ± 1.76		
3	10.64% sucrose	5.64% sucrose	11.7	<.001 ^{**}
	7.0 ± 1.85	4.8 ± 2.09		
4	10.64% sucrose	3.64% sucrose	19.8	<.001 ^{**}
	6.9 ± 1.47	3.2 ± 2.06		
5	10.64% sucrose	1.64% sucrose	22.8	<.001 ^{**}
	7.3 ± 1.53	2.6 ± 2.29		

^aNot significant

^{**}Significant at 1% ($p < .01$).

3.3 | Second part: Determination of the CAT ideal sweetness and influence of label information on consumer expectations

3.3.1 | Determination of the CAT ideal sweetness

The control sample showed a mean value of 4.25 ± 1.00 for ideal sweetness and the CAT sample had a mean value of 3.80 ± 0.95 . The two ideal sweetness scores differ at a 5% significance level according to the ANOVA test. The control sample obtained a higher mean score, 4.25, which fell between “slightly too sweet” and “just sweet enough,” and the CAT sample obtained a mean score of 3.80, which fell between “Not quite sweet enough” and “just sweet enough.”

A frequency chart was created to show the mean sweetness and more clearly demonstrate subject preference (Figure 4). The graph shows that 50% and 45% of subjects found the control sample and the CAT samples, respectively, “just sweet enough.” Nearly 20% of the subjects found the control sample “not quite sweet enough” and this percentage rose to 27% for the CAT sample. This indicates that some of the subjects tested preferred higher levels of sweetness. 15% of the subjects felt that the CAT sample was “a little too sweet.” Additionally, 18% of subjects rated the sample with 9.13% sucrose “slightly more intense than desired,” which demonstrates that some consumers prefer less sweetness.

TABLE 3 Regression models for t (Y1) and hedonic mean (Y2) values as a function of sucrose content (x), regression coefficients, and significance

Regression models	R^2	p (f)
Eq. (A.1) $Y1 = -292.07x + 28.647$	.9865	<.001**
Eq. (A.2) $Y2 = 54.835x + 1.5106$	.9833	<.001**

**Significant at 1% ($p < .01$).

3.3.2 | Influence of label information on consumer expectations

Table 4 shows the differences between the scores obtained in the three test sessions. Hedonic means were obtained during the different sessions (A, B, C) as well as t values for both the control (10.64% sucrose) and CAT sample (9.13% sucrose) yogurts, reflecting differences obtained for the label test and the blind test (Expectation—Column 5), and the informed test and blind test (Perceived Healthiness—Column 6). The control sample with 10.64% sucrose obtained a mean hedonic score that was significantly higher (7.5) than the CAT sample (7.1) in the first blind test session. These results were to be expected, because the CAT sample sucrose content was at a threshold level where sensory acceptance becomes compromised.

In the second session, samples with informative labels describing the CAT sample sugar reduction obtained significantly higher hedonic scores (6.8) than the control sample (6.4). The negative t values (Table 4) obtained by subtracting the difference between the second and first sessions (Expectation), where lower sensory scores were found for the first labeled products, reveal that the labeled samples incurred lower acceptance levels than the samples from the first session ($p < .01$) (Perceived Healthiness).

Results showed t value for yogurts where it was observed that nutritional information had a positive and significant impact ($p < .05$) on sensory acceptance of the CAT sample. Higher values for the control sample in Sessions A (Blind Test) and C (Informed Test), when compared to the CAT sample, indicated that the hedonic values were not less important than nutritional information. As expected in the first session, the CAT sample was less likely accepted than the control sample in the blind test. The ANOVA showed that nutritional information was able to improve acceptance of the CAT sample, so the control and CAT samples did not significantly differ in Session C. The positive t value for the CAT sample indicates that scores obtained in

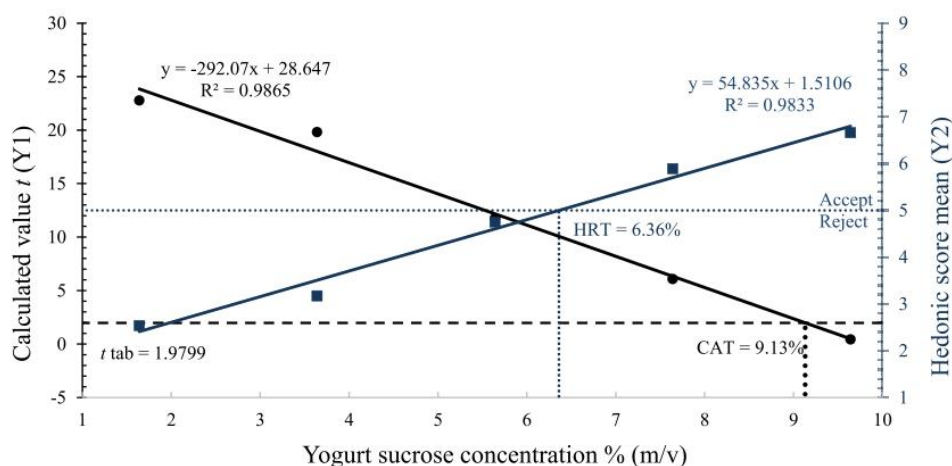
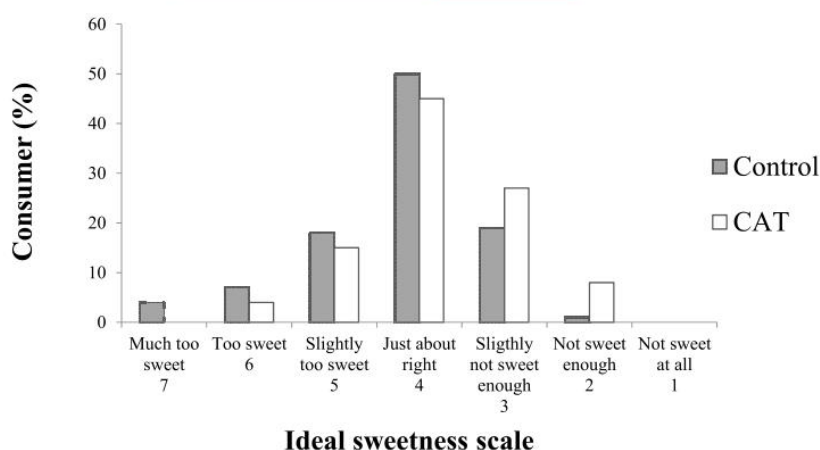


FIGURE 3 Calculated t -values and hedonic mean scores as a function of sucrose content in strawberry yogurt

FIGURE 4 Frequency of ideal sweetness scores**TABLE 4** Hedonic means and *t* values for blind test, label test, and informed test

Sample	Mean ± SD			T value	
	Session A (Blind test)	Session B (Label test)	Session C (Informed test)	Session B – Session A (Expectation)	Session C – Session A (Perceived healthiness)
Control	7.5 ^a ± 1.3	6.4 ^b ± 1.6	7.6 ^a ± 1.3	-6.689 ^{**}	0.276 ^{ns}
CAT	7.1 ^b ± 1.3	6.8 ^a ± 1.6	7.4 ^a ± 1.3	-1.825 ^{**}	2.549 [*]

Note: Means followed by the same letter in the column do not differ according to the F-test at 5% significance. ^{ns}Not significant ($p > .05$).

^{*}5% significance level ($p < .05$).

^{**}1% significance level ($p < .01$).

Session C were higher than those obtained in Session A, reflecting that perceived healthiness improved its sensory acceptability.

4 | DISCUSSION

One of the most important attributes of yogurt is its sweet taste, therefore reducing its sugar content without compromising its acceptance levels can be challenging (Barnes et al., 1991a; Barnes, Harper, Bodyfelt, & McDaniel, 1991b; Bayarri et al., 2011; Thompson et al., 2007). The HTM, unlike other traditional threshold methodologies (e.g., Difference Threshold, Detection Threshold), allows researchers to “track” acceptance behavior according to the stimulus studied and yield high-confidence values for the stimuli that take into account consumer opinion and therefore can be used by manufacturers. The CAT methodology can indicate stimulus limits which help avoid changes in acceptance when compared to control samples. It was found that samples with sucrose content exceeding 9.13% (CAT) in strawberry yogurt will yield the same sensory acceptance response as the control sample (10.64%) ($t < 1.9799$), at a 5% significance level (Figure 3). Therefore, the sucrose content in strawberry yogurt may be reduced by up to 14.1% without affecting consumer acceptance levels.

The Ministry of Health and Brazilian dairy manufacturers have set a maximum content of 12.8% sugar in yogurts to be implemented by 2022 (Brasil, 2018). To attain this goal, strawberry yogurt must have a

maximum addition of 9.42% sucrose when it is made (Table 1). This sucrose level is above the CAT sample results in the present study and therefore will lead to a similar sensory acceptance response as found for the control sample. It can be applied without reducing acceptance levels.

Although stimulus variability has not still been accurately established as a function of sensory acceptance, other studies have been able to reduce the sucrose content in foods without incurring sensory acceptance loss (Hoppert, Zahn, Puschmann, Ullmann, & Rohm, 2012; Li, Lopetcharat, Qiu, & Drake, 2015; Oliveira et al., 2018; Pineli et al., 2016). Although Oliveira et al. (2018) did not find a significant difference in the overall taste of fruit nectars with a 20% sugar reduction, there is a great heterogeneity in hedonic reactions in relation to sugar reduction, which depend mainly on the product. Dias, Sajiwani, and Rathnayaka (2020) reported that reducing sugar in probiotic yogurt to less than 3.5% is unacceptable from a sensory standpoint, and consumers are more tolerant of reducing fat than reducing sugar. Even so, Dias et al. (2020) reported that there is potential for reducing the total sugar by 7% (w/w) and the present study corroborated this result.

In a study by Oliveira et al. (2016), the difference threshold method was shown to be very conservative, because while consumers did detect differences between samples, the differences did not have an impact on sensory acceptance. They studied the difference threshold for sucrose in chocolate milk and compared a 6.4% reduced sucrose sample to a 9% sucrose control sample. When evaluating the

sensory characteristics of the samples certain attributes were found to differ, including the samples' chocolate flavor, sweetness and bitterness. However, for general acceptance purposes, both samples were deemed acceptable. The HTM establishes a direct relationship between stimulus intensity and sensory acceptance and does not infer that differences perceived by consumers will interfere with the sensory acceptance of a food. The method is useful in test situations and provides more accurate information on sensory acceptance. The present study showed that the production of strawberry yogurt with a sucrose concentration equal to or less than 6.36% (HRT) should be avoided (Figure 3), because these samples were sensorially rejected by evaluators. These low sugar levels in yogurt may generate losses in the dairy industry. Although they had lower acceptance levels than the control sample (10.64%), yogurt samples with sucrose contents between 6.36% and 9.13% still fell in the area of sensory acceptance. Thus, these percentages can be used in production, when necessary (Figure 3). Chollet, Gille, Schmid, Walther, and Piccinali (2013) obtained results that corroborate the findings of this article. The authors evaluated the sensorial acceptance of yogurt containing 10%, 7%, and 5% added sucrose. They found that yogurt with 7% sucrose, while deemed less acceptable than yogurt with 10% sucrose, also fell within an acceptance range, while yogurt with only 5% sucrose was rejected (Chollet et al., 2013).

In the present study, the control sample containing 10.64% sucrose was significantly sweeter than the CAT sample (Item 3.3.1). However, both samples obtained mean scores very close to 4 (almost perfectly sweet), suggesting that intermediate sucrose concentrations would also correspond to ideal sweetness levels. When Vickers, Holton, and Wang (1998) analyzed the sweetness of lemon yogurt, they obtained similar results and concluded that yogurt with a 9.3% sucrose content resulted in ideal sweetness scores. Despite these results, more studies are necessary to consider cultural differences among consumers and product differences.

Corroborating the findings of Chollet et al. (2013), the present study also showed that the ideal sweetness may vary among consumers. In order to study the ideal sweetness, these authors found that strawberry yogurt with 10% sugar was considered "very sweet" by 48% of consumers. It was found to be "almost perfect" by 44% and "not sweet enough" by less than 8%. Yogurt containing 7% sugar was also perceived as "almost ideal" by 44% of consumers. This means that yogurts with a different degree of sucrose can be perceived as ideal by different consumer groups. We also perceived that the CAT sample had lower acceptance levels than the control sample, but the sweetness level is close to the ideal sweetness, since 44% of consumers considered this sample to be ideal. Thus, it was seen that external factors improve the consumer experience and reduced the distance to the ideal sweetness, because nutritional information (expectation) was able to improve acceptance of the CAT sample, so that the control and CAT samples did not significantly differ regarding sensory acceptance.

In addition to adopting formulation and technological strategies, the inclusion of nutritional information on food labels is one of the most effective public policies for making informed and healthy food

choices (Grunert & Wills, 2007; Tórtora, Machin, & Ares, 2019). It is also a powerful tool that allows manufacturers to communicate with consumers (Celhay & Remaud, 2018). In the present study, it was shown that even a small amount of relevant information can improve consumer perceptions (Table 4). Because subject acceptance levels were lower for labeled samples than blind session samples (Session B – Session A), it can be inferred that the brand and label design were not responsible for the increase in acceptance levels of the CAT samples in Session C. Therefore, information on sugar reduction was the only possible factor. The second test session also makes it clear that products with labels which included information on sugar reduction had significantly higher acceptance levels than the control samples.

The test, which included information on sugar reduction, had a positive impact on acceptance levels of the CAT samples, whereas the information furnished with the control sample had no impact on its acceptance levels ($p > .05$). As a result, it was found that samples determined to be sensorially compromised (CAT) may reach the acceptance levels of the control sample when information on sugar reduction is provided (Table 4).

When it comes to stimulating the consumption of yogurt with reduced sugar and improving its perception, Hall, Lazard, Grummon, Mendel, and Taillie (2020) showed that health claims and health warnings compete in the perception of sugary drinks, where consumers direct more attention to health warnings information. This is especially important for marketing and to encourage more conscious choices for low or zero sugar yogurts. However, Lima, de Alcantara, Ares, and Deliza (2019) reinforced that although FOP labeling (front of the packaging) encouraged the selection of products with reduced sugar content, the hedonic experience in drinks with high sugar content remained more important at the time of selection because the hedonic experience nullified the effect of nutrition labeling on the front of the package. Dias et al. (2020) reported that sugar reductions to less than 3.5% compromised the sensory quality of yogurt because there was high sensory rejection at this concentration. Our study found that a sugar reduction of 14% sucrose can be adopted without compromising sensory acceptability. Torrico, Tam, Fuentes, Viejo, and Dunshea (2020) managed to further reduce sugar in strawberry yogurt, showing that analysis of the consumer rejection limit allowed for reducing sucrose to less than half of the initial concentration without affecting consumer preferences. In other food categories, Pineli et al. (2016) reported that sugar reductions could be up to 15% in nectar juice, while Oliveira et al. (2016) identified a sugar reduction of up to 29% in chocolate milk without affecting sensory acceptability. In order to elucidate safe reduction levels for industry and the consumer, additional studies with yogurt and other food categories in different cultures are needed, because to date the consumer appears to be more tolerant to fat reduction in yogurt than to sugar reduction (Dias et al., 2020). For example, Torrico et al. (2020) reported that the ideal level of sugar reduction in yogurt highly depends on the impact caused to its physicochemical properties, which in turn strongly interfere with preference and sensory acceptability.

It is worth noting that in addition to the sucrose concentration, the sweet taste can be further impaired by other factors such as

viscosity and fat content (Malone, Appelqvist, & Norton, 2003), which influence the perception process by facilitating (or not) the release of flavorings, their mixture with saliva and their interaction with taste receptors (Bayarri, Rivas, Izquierdo, & Costell, 2007). According to Kistler, Pridal, Bourcet, and Denkel (2020), it is possible to adapt the spatial and textural properties of products to modulate the sensory perception of taste, and sucrose and salt concentrations have already been successfully reduced to decrease, maintain or increase the intensity of sweetness and saltiness, respectively. Aaltonen, Kytö, Ylisjunttila-Huusko, and Outinen (2020) and Bertelsen et al. (2020) also highlighted the improved acceptance of reduced sugar products when textural improvements were made to the products. Mosca, van de Velde, Bult, van Boekel, and Stieger (2012) highlighted that the perception of sweetness can be increased by modulating the structural properties of food matrices since the firmness and homogeneous or heterogeneous distribution of sugar in the obtained gel promote a combined effect of texture and spatial distribution of sucrose that can generate healthier products with lower sugar contents. In addition, strategies for improving the perception of low sugar foods have also been significantly effective in leading consumers to repeated exposure to healthy stimuli (Lima, Ares, & Deliza, 2019), which may be a second way to popularize the consumption of low-sugar yogurt.

Packaging information can help companies leverage sucrose reduction when labels are used to draw consumers' attention to this feature and help influence product selection (Clement, Kristensen, & Grønhaug, 2013). The present study confirmed that labeling information may be succinct (Figure 1), and even when the label is superfluous (design, brand) the information helps improve consumer acceptance. It is important to consider that individuals with different degrees of health concern may counter or corroborate our findings. In addition, the effect of verbal and nonverbal information depends on a series of sociodemographic variables and social representations that may improve or worsen sensory acceptance. Pinto et al. (2020) perceived that the functional properties of Kefir were sufficient to improve the emotional profile of mixed yogurt and kefir beverages, but its influence on sensory acceptance also depended on the degree of kefir added to the mixed beverage and the degree of health concern.

Finally, it is worth noting that the CAT sample yogurt contained 12.46% carbohydrates (total sugars) (Table 1), which is lower than the regulatory levels that will come into effect in Brazil in 2022 (12.8%), with the potential to be commercialized.

5 | LIMITATIONS AND FUTURE PROSPECTS

The evaluation team utilized in the present study was made up of low health-conscious consumers, which complicates an analysis of their real health expectations (Appendix A). Participant age was a limitation because more than 64% of the participants were 18–25, and this age group is generally more likely to choose high-sugar products (Banik, Naher, Pervez, & Hossain, 2020; Dave, An, Jeffery, & Jasjit, 2009;

Schroder, Fito, & Covas, 2007; Valente, Stangarlin-Fiori, Seiscentos, de Souza, & Opolski, 2019). In this sense, research with elderly people is necessary since this age group is often more health conscious (Ares, Gimenez, & Gambaro, 2009; Baglione, Tucci, & Stanton, 2012; Cavaliere, Ricci, & Banterle, 2015; Karelakis, Zevgitis, Galanopoulos, & Mattas, 2019; Pinto et al., 2020) and may represent a new contrast between sensory acceptance and health expectations. According to Demattè et al. (2013), smell or taste loss in elderly individuals is one of the factors that causes a decline in their sensory perception, making them less intolerant to new foods (e.g., low-sugar products). The hedonic thresholds found in this study may thus be conservative, considering that older consumers who are more health-focused and aware of the effects of certain food ingredients may accept yogurts with lower sucrose levels.

The second limitation is concerning the flavor of the samples because strawberry corresponds to a popular flavor; future studies on uncommon flavors may counter or corroborate our findings. Third, the importance of considering the comparison between naturalistic environments would be interesting to assess whether there are emotions associated with the consumption of low-sugar yogurts since sadness and guilt have been shown to stimulate the consumption of sugary foods and drinks (Lefebvre, Hasford, & Wang, 2019). Assessing the extent to which emotions interfere with hedonic thresholds would be important to assist decision making regarding the safe level of sugar reduction to avoid economic and sensory losses for the industry. Only the reduction of sucrose was interpreted as a change in sensory acceptance, but small variations in the content of the other yogurt constituents could influence sensory characteristics and this needs to be evaluated in future studies.

It is worth mentioning that it was not possible to completely isolate the sucrose variable in this study. All yogurt samples underwent small changes in composition due to standardization prior to heat treatment and fermentation (for reasons previously explained). This may have contributed to small variations in sensory aspects. Thus, other technological characteristics must be investigated, such as how sugar reduction impacts yogurt viscosity and structure.

It is important to highlight other limitations of the present study which make it difficult to generalize the results. First, sensory perception is a multimodal phenomenon (Verhagen & Engelen, 2006), which implies that hedonic thresholds depend on different sensory characteristics of the product, each of which may have a greater or lesser impact on the compromised acceptance and rejection thresholds. Thus, while the study evaluated only the sugar concentration to determine hedonic thresholds, it demonstrated the importance of this variable in consumer hedonic acceptance and rejection. Future studies should consider the coexistence of two or more factors of variation to find more reliable results.

Qualitative future studies (e.g., observation research) and intervention studies would be important to assess how the consumer's attention is directed to the information present on the label, that is, what is the determinant information that influences consumer selection when considering purchase of a low-sugar yogurt (e.g., eye-tracking research). The results collected in the study may be used to

reduce sucrose and other ingredients in foods and thus contribute to nutritional improvements in Brazil and worldwide. Reducing sucrose in processed foods while maintaining their acceptance levels will help consumers reduce sugar intake and lead to a reduction of health risks, such as diabetes and obesity.

6 | CONCLUSION

In this study, it was demonstrated that more than 14% of sucrose in yogurt can be reduced without altering the sensory acceptance if compared to the quantity of sugar in a commercial yogurt product. It was also found that even when reductions affect consumer acceptance levels, including information on the label can turn an otherwise compromised sample into a sample that will be accepted as a commercial product, but a sucrose reduction of 40% or more leads to sensory rejection of strawberry yogurt. Other technological characteristics must be investigated, such as how sugar reduction impacts yogurt viscosity and structure, and cultural differences should also be considered in future studies.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Brazilian funding agencies CNPq (grants 315337/2018-4 and 311722/2016), Fapemig and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) – Finance Code 001, for the financial support.

ORCID

Louise Bergamin Athayde de Souza  <https://orcid.org/0000-0001-5218-5674>

Vinicius Rodrigues Arruda Pinto  <https://orcid.org/0000-0001-8935-6377>

Luis Gustavo Lima Nascimento  <https://orcid.org/0000-0001-8114-0774>

Rodrigo Stephani  <https://orcid.org/0000-0003-0237-8325>

Antonio Fernandes de Carvalho  <https://orcid.org/0000-0002-3238-936X>

Ítalo Tuler Perrone  <https://orcid.org/0000-0002-3393-4876>

REFERENCES

- Aaltonen, T., Kytö, E., Ylisjunttila-Huusko, S., & Outinen, M. (2020). Effect of the milk-based ash-protein ratio on the quality and acceptance of chocolate with a reduced sugar content. *International Dairy Journal*, 105, 104663.
- Allen, A. L., McGeary, J. E., & Hayes, J. E. (2013). Rebaudioside A and rebaudioside D bitterness do not covary with acesulfame-K bitterness or polymorphisms in TAS2R9 and TAS2R31. *Chemosens. Perception*, 6, 109–117. <https://doi.org/10.1007/s12078-013-9149-9>
- AOAC International (2016). In G. W. Latimer (Ed.), *Official methods of analysis* (20th ed., pp. 20850–23250). Rockville, MD: AOAC International.
- Ares, G., Giménez, A., & Gambaro, A. (2008). Understanding consumers' perception of conventional and functional yogurts using word association and hard ladderling. *Food Quality and Preference*, 19, 636–643. <https://doi.org/10.1016/j.foodqual.2008.05.005>
- Ares, G., Gimenez, A., & Gambaro, A. (2009). Consumer perceived healthiness and willingness to try functional milk desserts. Influence of ingredient, ingredient name and health claim. *Food Quality and Preference*, 20, 50–56. <https://doi.org/10.1016/j.foodqual.2008.07.002>
- Baglione, S. L., Tucci, L. A., & Stanton, J. L. (2012). Self-reported nutritional knowledge and the acceptance of health-related food benefit claims. *British Food Journal*, 114, 453–468. <https://doi.org/10.1108/00070701211219496>
- Banik, R., Naher, S., Pervez, S., & Hossain, M. M. (2020). Fast food consumption and obesity among urban college going adolescents in Bangladesh: A cross-sectional study. *Obesity Medicine*, 17(2020), 100161. <https://doi.org/10.1016/j.obmed.2019.100161>
- Barnes, D. L., Harper, S. J., Bodyfelt, F. W., & McDaniel, M. R. (1991a). Correlation of descriptive and consumer panel flavor ratings for commercial prestirred strawberry and lemon yogurts. *Journal of Dairy Science*, 74, 2089–2099. [https://doi.org/10.3168/jds.S0022-0302\(91\)78381-1](https://doi.org/10.3168/jds.S0022-0302(91)78381-1)
- Barnes, D. L., Harper, S. J., Bodyfelt, P. W., & McDaniel, M. R. (1991b). Prediction of consumer acceptability of yogurt by sensory and analytical measures of sweetness and sourness. *Journal of Dairy Science*, 74, 3746–3754. [https://doi.org/10.3168/jds.S0022-0302\(91\)78566-4](https://doi.org/10.3168/jds.S0022-0302(91)78566-4)
- Bayarri, S., Carbonell, I., Barrios, E. X., & Costell, E. (2011). Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. *International Dairy Journal*, 21, 111–118. <https://doi.org/10.1016/j.idairyj.2010.09.002>
- Bayarri, S., Rivas, I., Izquierdo, L., & Costell, E. (2007). Influence of texture on the temporal perception of sweetness of gelled systems. *Food Research International*, 40, 900–908. <https://doi.org/10.1016/j.foodres.2007.03.003>
- Bertelsen, A. S., Zeng, Y., Mielby, L. A., Sun, Y.-X., Byrne, D. V., & Kidmose, U. (2020). Cross-modal effect of vanilla aroma on sweetness of different sweeteners among Chinese and Danish consumers. *Food Quality and Preference*, 87, 104036. <https://doi.org/10.1016/j.foodqual.2020.104036>
- Biguzzi, C., Schlich, P., & Lange, C. (2014). The impact of sugar and fat reduction on perception and liking of biscuits. *Food Quality and Preference*, 35, 41–47. <https://doi.org/10.1016/j.foodqual.2014.02.001>
- Boring, E. G. (1946). *Sensation and perception in the history of experimental psychology* (1st ed.). New York, NY: Appleton Century Crofts.
- Brasil. (2003). Agência Nacional de Vigilância Sanitária. Regulamento Técnico para declaração de rotulagem nutricional. Resolução - RDC nº 359, de 23 de dezembro de 2003. Diário Oficial da República Federativa do Brasil.
- Brasil. (2007). Ministério da Agricultura, Pecuária e Abastecimento. Regulamento Técnico de Identidade e Qualidade (RTIQ) de Leites Fermentados. Instrução Normativa n. 46, de 23 de outubro de 2007. Diário Oficial da República Federativa do Brasil. (Seção 1, pp. 4).
- Brasil. (2018). Ministério da Saúde. Termo de compromisso para o estabelecimento de metas nacionais para a redução do teor de açúcares em alimentos industrializados no Brasil. Retrieved from: <http://portalarquivos2.saude.gov.br/images/pdf/2018/novembro/26/termo-de-compromisso-reducao-acucar.pdf>
- Buckton, C. H., Hyseni, L., Patterson, C., Katikireddi, S. V., Lloyd-Williams, F., Elliot-Green, A., ... Hilton, S. (2017). Media representations of sugar and sugar-sweetened beverage consumption in UK newspapers: Implications for public health policy. *The Lancet*, 390, S27. [https://doi.org/10.1016/S0140-6736\(17\)32962-8](https://doi.org/10.1016/S0140-6736(17)32962-8)
- Cadena, R. S., Cruz, A. G., Faria, H. M. A., & Bolini, J. A. F. (2012). Reduced fat and sugar vanilla ice creams: Sensory profiling and external preference mapping. *Journal of Dairy Science*, 95, 4842–4850. <https://doi.org/10.3168/jds.2012-5526>
- Capacci, S., Mazzocchi, M., Shankar, B., Macias, J. B., Verbeke, W., Perez-Cueto, F. J. A., ... Traill, W. B. (2012). Policies to promote healthy eating in Europe: A structured review of policies and their effectiveness.

- Nutrition Reviews*, 70, 188–200. <https://doi.org/10.1111/j.1753-4887.2011.00442.x>
- Carocho, M., Morales, P., & Ferreira, I. C. F. R. (2017). Sweeteners as food additives in the XXI century: A review of what is known, and what is to come. *Food and Chemical Toxicology*, 107, 302–317. <https://doi.org/10.1016/j.fct.2017.06.046>
- Cavaliere, A., Ricci, E. C., & Banterle, A. (2015). Nutrition and health claims: Who is interested? An empirical analysis of consumer preferences in Italy. *Food Quality and Preference*, 41, 44–51. <https://doi.org/10.1016/j.foodqual.2014.11.002>
- Celhay, F., & Remaud, H. (2018). What does your wine label mean to consumers? A semiotic investigation of Bordeaux wine visual codes. *Food Quality and Preference*, 65, 129–145. <https://doi.org/10.1016/j.foodqual.2017.10.020>
- Chattopadhyay, S., Raychaudhuri, U., & Chakraborty, R. (2014). Artificial sweeteners - A review. *Journal of Food Science and Technology*, 51, 611–621. <https://doi.org/10.1007/s13197-011-0571-1>
- Chollet, M., Gille, D., Schmid, A., Walther, B., & Piccinali, P. (2013). Acceptance of sugar reduction in flavored yogurt. *Journal of Dairy Science*, 96, 5501–5511. <https://doi.org/10.3168/jds.2013-6610>
- Clement, J., Kristensen, T., & Grønhaug, K. (2013). Understanding consumers' in-store visual perception: The influence of package design features on visual attention. *Journal of Retailing and Consumer Services*, 20, 234–239. <https://doi.org/10.1016/j.jretconser.2013.01.003>
- Dantas, M. I. S., Minim, V. P. R., & Deliza, R. (2003). Tradução e validação para a língua portuguesa do questionário Health Consciousness utilizado em estudos de consumidor. *Boletim sbCTA*, 37, 103–105. <https://doi.org/10.1590/S0101-206120030001000010>
- Dave, J. M., An, L. C., Jeffery, R. W., & Jasjit, S. A. (2009). Relationship of attitudes toward fast food and frequency of fast-food intake in adults. *Obesity (Silver Spring)*, 17, 1164–1170. <https://doi.org/10.1038/oby.2009.26>
- Della Lucia, S. M., Minim, V. P. R., Silva, C. H. O., Minim, L. A., & Cipriano, P. A. (2013). Ordered probit regression analysis of the effect of brand name on beer acceptance by consumers. *Food Science and Technology*, 33, 586–591. <https://doi.org/10.1590/S0101-20612013005000068>
- Della Lucia, S. M., Minim, V. P. R., Silva, C. H. O., Minim, L. A., & Cipriano, P. A. (2014). Use of relative risk test to evaluate the influence of the brand on beer acceptability. *Semina: Ciências Agrárias*, 35, 267–276. <https://doi.org/10.5433/1679-0359.2014v35n1p267>
- Demattè, M. L., Endrizzi, I., Biasioli, F., Corollaro, M. L., Pojer, N., Zampini, M., & Gasperi, F. (2013). Food neophobia and its relation with olfactory ability in common odour identification. *Appetite*, 68, 112–117. <https://doi.org/10.1016/j.appet.2013.04.021>
- Dias, P. G. I., Sajiwani, J. W. A., & Rathnayaka, R. M. U. S. K. (2020). Consumer perception and sensory profile of probiotic yogurt with added sugar and reduced milk fat. *Heliyon*, 6(7), e04328. <https://doi.org/10.1016/j.heliyon.2020.e04328>
- Grimes, C. A., Riddell, L. J., & Nowson, C. A. (2009). Consumer knowledge and attitudes to salt intake and labelled salt information. *Appetite*, 53, 189–194. <https://doi.org/10.1016/j.appet.2009.06.007>
- Grummon, A. H., Smith, N. R., Golden, S. D., Frerichs, L., Taillie, L. S., & Brewer, N. T. (2019). Health warnings on sugar-sweetened beverages: Simulation of impacts on diet and obesity among U.S. adults. *American Journal of Preventive Medicine*, 57, 765–774. <https://doi.org/10.1016/j.amepre.2019.06.022>
- Grunert, K. G., & Wills, J. M. (2007). A review of European research on consumer response to nutrition information on food labels. *Journal of Public Health*, 15, 385–399. <https://doi.org/10.1007/s10389-007-0101-9>
- Hagmann, D., Siegrist, M., & Hartmann, C. (2018). Taxes, labels, or nudges? Public acceptance of various interventions designed to reduce sugar intake. *Food Policy*, 79, 156–165. <https://doi.org/10.1016/j.foodpol.2018.06.008>
- Hall, M. G., Lazard, A. J., Grummon, A. H., Mendel, J. R., & Taillie, L. S. (2020). The impact of front-of-package claims, fruit images, and health warnings on consumers' perceptions of sugar-sweetened fruit drinks: Three randomized experiments. *Preventive Medicine*, 132, 105998. <https://doi.org/10.1016/j.ypmed.2020.105998>
- Hernández-Morales, C., Hernández-Montes, A., & Villegas-de Gante, A. (2007). Effect of the partial substitution of sucrose by neotame on the sensory and consistency characteristics of plain yogurt. *Revista Mexicana de Ingeniería Química*, 6, 203–209.
- Hoppert, K., Zahn, S., Puschmann, A., Ullmann, I., & Rohm, H. (2012). Quantification of sensory difference thresholds for fat and sweetness in dairy-based emulsions. *Food Quality and Preference*, 26, 52–57. <https://doi.org/10.1016/j.foodqual.2012.03.008>
- Hutkins, R. W. (2006). *Microbiology and technology of fermented foods*. Chicago, Hoboken, NJ: Wiley Blackwell Publishing. <https://doi.org/10.1002/9780470277515>
- Johansen, S. B., Næs, T., Øyaas, J., & Hersleth, M. (2010). Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. *Food Quality and Preference*, 21, 13–21. <https://doi.org/10.1016/j.foodqual.2009.07.003>
- Kalicka, D., Znamirska, A., Buniowska, M., Esteve Más, M. J., & Canoves, A. F. (2017). Effect of stevia addition on selected properties of yoghurt during refrigerated storage. *Polish Journal of Natural Science*, 32, 323–334.
- Karelakis, C., Zevgitis, P., Galanopoulos, K., & Mattas, K. (2019). Consumer trends and attitudes to functional foods. *Journal of International Food & Agribusiness Marketing*, 32, 266–294. <https://doi.org/10.1080/08974438.2019.1599760>
- Keefer, H. R. M., Nishku, S., Gerard, P. D., & Drake, M. A. (2020). Role of sweeteners on temporality and bar hardening of protein bars. *Journal of Dairy Science*, 103, 6032–6053. <https://doi.org/10.3168/jds.2019-17995>
- Kim, S. Y., Nayga, R. M., & Capps, O. (2020). The effect of food label use on nutrient intakes: An endogenous switching regression analysis. *Journal of Agricultural and Resource Economics*, 25, 215–231. <https://doi.org/10.22004/ag.econ.30831>
- King, B. M., Arents, P., & Duineveld, C. A. A. (2003). A comparison of aspartame and sucrose with respect to carryover effects in yogurt. *Food Quality and Preference*, 14, 75–81, 2003. [https://doi.org/10.1016/s0950-3293\(02\)00054-x](https://doi.org/10.1016/s0950-3293(02)00054-x)
- King, S. C., Lawler, P. J., & Adams, J. K. (2005). Effect of aspartame and fat on sweetness perception in yogurt. *Journal of Food Science*, 65, 1056–1059. <https://doi.org/10.1111/j.1365-2621.2000.tb09417.x>
- Kistler, T., Pridal, A., Bourcet, C., & Denkel, C. (2020). Modulation of sweetness perception in confectionary applications. *Food Quality and Preference*, 88, 104087. <https://doi.org/10.1016/j.foodqual.2020.104087>
- Labropoulos, A. E., Collins, W. F., & Stone, W. K. (1984). Effects of ultra-high temperature and vat processes on heat-induced rheological properties of yogurt. *Journal of Dairy Science*, 67, 405–409. [https://doi.org/10.3168/jds.S0022-0302\(84\)81316-8](https://doi.org/10.3168/jds.S0022-0302(84)81316-8)
- Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: Principles and practices* (2nd ed.). New York, NY: Springer. <https://doi.org/10.1007/978-1-4419-6488-5>
- Lee, W. J., & Lucey, J. A. (2003). Rheological properties, whey separation, and microstructure IN set-style yogurt: Effects OF heating temperature and incubation temperature. *Journal of Texture Studies*, 34, 515–536. <https://doi.org/10.1111/j.1745-4603.2003.tb01079.x>
- Lefebvre, S., Hasford, J., & Wang, Z. (2019). The effects of guilt and sadness on sugar consumption. *Journal of Business Research*, 100, 130–138. <https://doi.org/10.1016/j.jbusres.2019.03.023>
- Li, X. E., Lopetcharat, K., Qiu, Y., & Drake, M. A. (2015). Sugar reduction of skim chocolate milk and viability of alternative sweetening through lactose hydrolysis. *Journal of Dairy Science*, 98, 1455–1466. <https://doi.org/10.3168/jds.2014-8490>

- Lima Filho, T., Della Lucia, S. M., Minim, L. A., Gamba, M. M., Lima, R. M., & Minim, V. P. R. (2019). Directional hedonic thresholds for sodium concentration in hamburger. *Food Quality and Preference*, 78, 103722. <https://doi.org/10.1016/j.foodqual.2019.103722>
- Lima Filho, T., Della Lucia, S. M., Minim, L. A., Silva, R. C. S. N., Silva, A. N., & Minim, V. P. R. (2017). Validation of the hedonic threshold methodology in determining the compromised acceptance threshold. *Journal of Sensory Studies*, 32, 1–12. <https://doi.org/10.1111/joss.12255>
- Lima Filho, T., Della Lucia, S. M., Minim, L. A., Silva, R. C. S. N., Silva, A. N., & Minim, V. P. R. (2018). Validation of the hedonic threshold methodology in determining the hedonic rejection threshold. *Journal of Sensory Studies*, 33, 1–13. <https://doi.org/10.1111/joss.12313>
- Lima Filho, T., Minim, V. P. R., Navarro, R. D. C., Della Lucia, S. M., & Minim, L. A. (2015). Methodology for determination of two new sensory thresholds: Compromised acceptance threshold and rejection threshold. *Food Research International*, 76, 561–566. <https://doi.org/10.1016/j.foodres.2015.07.037>
- Lima, M., Ares, G., & Deliza, R. (2019). Comparison of two sugar reduction strategies with children: Case study with grape nectars. *Food Quality and Preference*, 71, 163–167. <https://doi.org/10.1016/j.foodqual.2018.07.002>
- Lima, M., de Alcantara, M., Ares, G., & Deliza, R. (2019). It is not all about information! Sensory experience overrides the impact of nutrition information on consumers' choice of sugar-reduced drinks. *Food Quality and Preference*, 74, 1–9. <https://doi.org/10.1016/j.foodqual.2018.12.013>
- Lytton, T. D. (2010). Signs of change or clash of symbols? FDA regulation of nutrient profile labelling. *Health Matrix (Cleveland, Ohio)*, 20, 93–144.
- Ma, Y., He, F. J., Yin, Y., Hashem, K. M., & McGregor, G. A. (2016). Gradual reduction of sugar in soft drinks without substitution as a strategy to reduce overweight, obesity, and type 2 diabetes: A modelling study. *The Lancet Diabetes and Endocrinology*, 4, 105–114.
- Macgregor, G. A., & Hashem, K. M. (2014). Action on sugar - lessons from UK salt reduction programme. *Lancet*, 383, 929–931. [https://doi.org/10.1016/S0140-6736\(14\)60200-2](https://doi.org/10.1016/S0140-6736(14)60200-2)
- Malone, M. E., Appelqvist, I. A. M., & Norton, I. T. (2003). Oral behaviour of food hydrocolloids and emulsions. Part 2. Taste and aroma release. *Food Hydrocolloids*, 17, 775–784. [https://doi.org/10.1016/S0268-005X\(03\)00098-5](https://doi.org/10.1016/S0268-005X(03)00098-5)
- Markey, O., Lovegrove, J. A., & Methven, L. (2015). Sensory profiles and consumer acceptability of a range of sugar-reduced products on the UK market. *Food Research International*, 72, 133–139. <https://doi.org/10.1016/j.foodres.2015.03.012>
- Miele, N. A., Cabisidan, E. K., Blaiotta, G., Leone, S., Masi, P., Di Monaco, R., & Cavella, S. (2017). Rheological and sensory performance of a protein-based sweetener (MNEI), sucrose, and aspartame in yogurt. *Journal of Dairy Science*, 100, 9539–9550. <https://doi.org/10.3168/jds.2017-12894>
- Mosca, A. C., van de Velde, F., Bult, J. H. F., van Boekel, M. A. J. S., & Stieger, M. (2012). Effect of gel texture and sucrose spatial distribution on sweetness perception. *LWT - Food Science and Technology*, 46(1), 183–188. <https://doi.org/10.1016/j.lwt.2011.10.009>
- Oliveira, D., Galhardo, J., Ares, G., Cunha, L. M., & Deliza, R. (2018). Sugar reduction in fruit nectars: Impact on consumers' sensory and hedonic perception. *Food Research International*, 107, 371–377. <https://doi.org/10.1016/j.foodres.2018.02.025>
- Oliveira, D., Reis, F., Deliza, R., Rosenthal, A., Giménez, A., & Ares, G. (2016). Difference thresholds for added sugar in chocolate-flavoured milk: Recommendations for gradual sugar reduction. *Food Research International*, 89, 448–453. <https://doi.org/10.1016/j.foodres.2016.08.019>
- Pamell-Clunies, E., Kakuda, Y., de Man, J. M., & Cazzola, F. (1988). Gelation profiles of yogurt as affected by heat treatment of Milk. *Journal of Dairy Science*, 71, 582–588. [https://doi.org/10.3168/jds.S0022-0302\(88\)79594-6](https://doi.org/10.3168/jds.S0022-0302(88)79594-6)
- Pineli, L. L. O., Aguiar, L. A., Fiusa, A., Botelho, R. B. A., Zandonadi, R. P., & Melo, L. (2016). Sensory impact of lowering sugar content in orange nectars to design healthier, low-sugar industrialized beverages. *Appetite*, 96, 239–244. <https://doi.org/10.1016/j.appet.2015.09.028>
- Pinheiro, M. V. S., Oliveira, M. N., Penna, A. L. B., & Tamime, A. Y. (2005). The effect of different sweeteners in low-calorie yogurts—A review. *International Journal of Dairy Technology*, 58, 193–199.
- Pinto, V. R. A., Teixeira, C. G., Lima, T. S., Prata, E. R. B. A., Vidígal, M. C. T. R., Martins, E., ... Carvalho, A. F. (2020). Health beliefs towards kefir correlate with emotion and attitude: A study using an emoji scale in Brazil. *Food Research International*, 129, 108833. <https://doi.org/10.1016/j.foodres.2019.108833>
- Pohjanheimo, T., & Sandell, M. (2009). Explaining the liking for drinking yoghurt: The role of sensory quality, food choice motives, health concern and product information. *International Dairy Journal*, 19, 459–466. <https://doi.org/10.1016/j.idairyj.2009.03.004>
- Raaij, J. V., Hendriksen, M., & Verhagen, H. (2009). Potential for improvement of population diet through reformulation of commonly eaten foods. *Public Health Nutrition*, 12, 325–330. <https://doi.org/10.1017/S1368980008003376>
- Reis, F., Alcaire, F., Deliza, R., & Ares, G. (2017). The role of information on consumer sensory, hedonic and wellbeing perception of sugar-reduced products: Case study with orange/pomegranate juice. *Food Quality and Preference*, 62, 227–236. <https://doi.org/10.1016/j.foodqual.2017.06.005>
- Routray, W., & Mishra, H. N. (2011). Scientific and technical aspects of yogurt aroma and taste: A review. *Comprehensive Reviews in Food Science and Food Safety*, 10, 208–220. <https://doi.org/10.1111/j.1541-4337.2011.00151.x>
- Schiffman, S. S., Booth, B. J., Losee, M. L., Pecore, S. D., & Warwick, Z. S. (1995). Bitterness of sweeteners as a function of concentration. *Brain Research Bulletin*, 36, 505–513. [https://doi.org/10.1016/0361-9230\(94\)00225](https://doi.org/10.1016/0361-9230(94)00225)
- Schroder, H., Fito, M., & Covas, M. I. (2007). Association of fast food consumption with energy intake, diet quality, body mass index and the risk of obesity in a representative Mediterranean population. *British Journal of Nutrition*, 98, 1274–1280.
- Shangguan, S., Afshin, A., Shulkin, M., Ma, W., Marsden, D., Smith, J., ... Mozaffarian, D. (2019). A meta-analysis of food labeling effects on consumer diet behaviors and industry practices. *American Journal of Preventive Medicine*, 56, 300–314. <https://doi.org/10.1016/j.amepre.2018.09.024>
- Shim, S.-M., Seo, S. H., Lee, Y., Moon, G.-I., Kim, M.-S., & Park, J.-H. (2011). Consumers' knowledge and safety perceptions of food additives: Evaluation on the effectiveness of transmitting information on preservatives. *Food Control*, 22, 1054–1060. <https://doi.org/10.1016/j.foodcont.2011.01.001>
- Sodini, I., Lucas, A., Oliveira, M. N., Remeuf, F., & GCorrieu, G. (2002). Effect of milk base and starter culture on acidification, texture, and probiotic cell counts in fermented milk processing. *Journal of Dairy Science*, 85, 2479–2488. [https://doi.org/10.3168/jds.S0022-0302\(02\)74330-0](https://doi.org/10.3168/jds.S0022-0302(02)74330-0)
- Stacey, N., Mudara, C., Ng, S. W., Walbeek, C., Hofman, K., & Edoka, I. (2019). Sugar-based beverage taxes and beverage prices: Evidence from South Africa's health promotion levy. *Social Science & Medicine*, 238, 112465. <https://doi.org/10.1016/j.socscimed.2019.112465>
- Tan, V. W. K., Wee, M. S. M., Tomic, O., & Forde, C. G. (2020). Rate-all-that-apply (RATA) comparison of taste profiles for different sweeteners in black tea, chocolate milk, and natural yogurt. *Journal of Food Science*, 85, 486–492. <https://doi.org/10.1111/1750-3841.15007>
- Thompson, J. L., Lopetcharat, K., & Drake, M. A. (2007). Preferences for commercial strawberry drinkable yogurts among African American, Caucasian, and Hispanic consumers in the United States. *Journal of Dairy Science*, 90, 4974–4987. <https://doi.org/10.3168/jds.2007-0313>

- Torrice, D. D., Tam, J., Fuentes, S., Viejo, C. G., & Dunshea, F. R. (2020). Consumer rejection threshold, acceptability rates, physico-chemical properties, and shelf-life of strawberry flavored yogurts with reductions of sugar. *Journal of the Science of Food and Agriculture*, 100, 3024–3035. <https://doi.org/10.1002/jsfa.10333>
- Tórtora, G., Machín, L., & Ares, G. (2019). Influence of nutritional warnings and other label features on consumers' choice: Results from an eye-tracking study. *Food Research International*, 119, 605–611. <https://doi.org/10.1016/j.foodres.2018.10.038>
- Valente, G. M., Stangarlin-Fiori, L., Seiscentos, L. D. O., de Souza, V. V., & Opolski, M. C. (2019). Profile of food truck consumers and their opinion about food safety. *Nutrition & Food Science*, 50, 481–495. <https://doi.org/10.1108/NFS-05-2019-0162>
- Verhagen, J. V., & Engelen, L. (2006). The neurocognitive bases of human multimodal food perception: Sensory integration. *Neuroscience and Biobehavioral Reviews*, 30, 613–650.
- Vickers, Z., Holton, E., & Wang, J. (1998). Effect of yogurt sweetness on sensory specific satiety. *Journal of Sensory Studies*, 13, 377–388. <https://doi.org/10.1111/j.1745-459X.1998.tb00096.x>
- Vreman, R. A., Goodell, A. J., Rodriguez, L. A., Porco, T. C., Lustig, R. H., & Kahn, J. G. (2017). Health and economic benefits of reducing sugar intake in the USA, including effects via non-alcoholic fatty liver disease: A microsimulation model. *BMJ Open*, 7, e013543. <https://doi.org/10.1136/bmjopen-2016-013543>
- Wagoner, T. B., McCain, H. R., Foegeding, E. A., & Drake, M. A. (2018). Food texture and sweetener type modify sweetness perception in whey protein-based model foods. *Journal of Sensory Studies*, 33, 33e12333. <https://doi.org/10.1111/joss.12333>
- Wang, Y. C., Coxson, P. Y., Shen, M., Goldman, L., & Bibbins-Domingo, K. (2012). A penny-per-ounce tax on sugar-sweetened beverages would cut health and cost burdens of diabetes. *Health Affairs (Millwood)*, 31, 199–207. <https://doi.org/10.1377/hlthaff.2011.0410>
- World Health Organization - WHO (2015). Guideline: Sugars intake for adults and children. Geneva. Retrieved from: <http://www.who.int/nutrition/publications/guidelines>.

How to cite this article: de Souza LBA, Pinto VRA, Nascimento LGL, Stephani R, de Carvalho AF, Perrone ÍT. Low-sugar strawberry yogurt: Hedonic thresholds and expectations. *J Sens Stud*. 2021;e12643. <https://doi.org/10.1111/joss.12643>

APPENDIX A.

Profile of the participants for determination of the Hedonic Thresholds

Among the participants, 69% completed high school, 90% had an income of up to 10 minimum wages, more than 50% of the participants consumed yogurt at least twice a week, 73% stated that the strawberry flavor is that most consumed, 77% ingested whole yogurt (with fat) and 86% of consumers ingested the yogurt with sugar, a little more than 50% of consumers said they frequently read the labels of food products, 36% stated that they often worry about the quantity of sugar ingested, and 23% are rarely concerned with the amount of sugar ingested. Only 6.7% are always concerned with sugar intake.

According to the Health Consciousness Scale questionnaire, 16.53% of the participants were classified as highly concerned with health, 17.35% had low concern for health, and 66.12% had moderate concern for health.

3. CAPÍTULO 2

Gordura Superficial em leite em pó

GORDURA SUPERFICIAL EM LEITE EM PÓ**Fat in the milk powder surface**

Louise Bergamin Athayde de Souza¹, Gabriel Gama Netto¹, Karina Coelho Moreira da Silva¹, Rodrigo Stephani², Antônio Fernandes de Carvalho¹, Ítalo Tuler Perrone^{3}*

RESUMO

O leite em pó é um produto altamente versátil, fabricado geralmente por meio da técnica de *spray drying*, que consiste na remoção de grande parte da água expondo o produto a uma corrente de ar quente. Esse produto possui prazo de validade superior ao leite *in natura* e oferece diversas comodidades, como maior estabilidade microbiológica e química e condições de armazenamento menos restritas. Entretanto, um grande acúmulo de gordura na superfície desses pós tem sido vastamente documentado em diversas partes do mundo. Frações dessa gordura que se apresenta na camada externa do pó estão na forma livre sendo associadas a características indesejáveis do produto, como dificuldades de reidratação, oxidação de lipídios, aumento de viscosidade e outros, levando a redução de qualidade do produto. Maneiras de reduzir esse teor de gordura têm sido buscadas para amenizar os efeitos indesejáveis e uma das formas promissoras parece ser pela estabilização da matriz láctea antes das etapas de atomização e secagem. Nessa revisão bibliográfica será abordada as características do leite em pó, características da gordura, assim como ocorrência da gordura superficial, os causadores e algumas das possíveis soluções do problema.

Palavras-chave: lácteos desidratados; gordura livre; molhabilidade; pós lácteos.

ABSTRACT

Milk powder is a highly versatile product produced by spray drying, which

1 Universidade Federal de Viçosa, Departamento de Tecnologia de Alimentos, Viçosa, MG, Brasil

2 Universidade Federal de Juiz de Fora, Departamento de Química, Juiz de Fora, MG, Brasil.

3 Universidade Federal de Juiz de Fora, Faculdade de Farmácia, Rua José Lourenço Kelmer, s/n, São Pedro, 36036-900, Juiz de Fora, MG, Brasil. E-mail: italotulerperrone@gmail.com

* Autor para correspondência.

Recebido / Received: 17/03/2020

Aprovado / Approved: 18/12/2020

consists of removing water by exposing the product to a flow of dry and hot air. This product has a longer shelf life than fresh milk and offers positive points, such as greater microbiological and chemical stability and less restricted storage conditions. However, a large migration of fat to the surface of these powders has been widely documented in several studies. Part of this fat present on the powder surface is in the free form and associated with undesirable characteristics of the product, such as rehydration difficulties, lipid oxidation, increased viscosity, and others, leading to reduced product quality. Stabilizing the milk emulsion matrix before the atomization and drying steps is the best way to avoid free fat. In this bibliographic review, the characteristics of milk powder, characteristics of fat, as well as the occurrence of superficial free fat, the causes, and some of the possible solutions will be aborded.

Keywords: dehydrated dairy products; free fat; wettability; dairy powders.

INTRODUÇÃO

O leite e seus derivados merecem destaque por constituírem um grupo de alimentos de grande valor nutricional, uma vez que são fontes consideráveis de proteínas de alto valor biológico, além de conterem vitaminas e minerais. O consumo habitual desses alimentos é recomendado, principalmente, para que se atinja a adequação diária de ingestão de cálcio, um nutriente que, dentre outras funções, é fundamental para a formação e a manutenção da estrutura óssea do organismo (MUNIZ *et al.*, 2013).

O leite em pó é um derivado do leite, sendo uma forma prática de consumo do mesmo, que é obtido pela concentração e desidratação do leite, que pode ser integral, semidesnatado ou desnatado. O objetivo da desidratação do leite é estabilizar os constituintes para seu armazenamento e uso posterior, pela redução da atividade de água do produto, levando a maior vida de prateleira (PISECKY, 2012).

É um alimento muito valioso e nutritivo, que pode ser usado como ingrediente na formulação de uma gama enorme de produtos, incluindo produtos de confeitaria, molhos, massas e até produtos farmacêuticos. Além disso, ao ser reconstituído, volta a ter características do leite fluido. Entretanto, para que

essa reconstituição seja adequada, é necessário que esse produto atenda algumas exigências, como ter características adequadas de molhabilidade, dispersibilidade, solubilidade e penetrabilidade, que dependem de diversos fatores, entre eles as características da superfície da partícula (CARVALHO *et al.*, 2020).

Durante as etapas de processamento geralmente ocorre uma camada indesejada de gordura sobre a superfície das partículas, sendo composta por frações de gordura livre que leva a efeitos prejudiciais nas propriedades do pó, incluindo solubilidade reduzida na água, oxidação de lipídios, aumento de viscosidade e perda da qualidade do produto (MURRIETA-PAZOS *et al.*, 2012).

Diversos estudos têm documentado uma grande quantidade de gordura na superfície dos pós, que ocorre principalmente durante as etapas de atomização e secagem, e seus efeitos prejudiciais. Tem-se notado que possivelmente maneiras eficientes de se reduzir esse teor de gordura pode ser pela estabilização da matriz láctea antes dela passar por esses processos, de modo que o glóbulo de gordura esteja mais protegido antes de sofrer as alterações (FOERSTER *et al.*, 2017a; FOERSTER *et al.*, 2016a; FOERSTER *et al.*, 2016b).

Conhecer as características dessa gordura e procurar maneiras de reduzi-la se

faz necessário para aumentar a qualidade do leite em pó e outros produtos lácteos que apresentam esse mesmo problema (VIGNOLLES *et al.*, 2007).

Essa revisão tem como foco abranger as características do leite em pó, de sua gordura, os relatos sobre esse acúmulo superficial de gordura e indicar algumas alternativas para redução do problema trazido.

REVISÃO DE LITERATURA

Leite em pó

Entende-se por leite em pó o produto que se obtém por desidratação do leite, integral, desnatado ou parcialmente desnatado e apto para a alimentação humana, mediante processos tecnologicamente adequados. É classificado como integral quando o teor de gordura for maior ou igual a 26,0%, desnatado quando o teor de gordura for menor ou igual a 1,5% de gordura e parcialmente desnatado se o teor de gordura for maior do que 1,5% e menor que 26,0%. Pode ser classificado como instantâneo ou não, a depender de sua umectabilidade e dispersibilidade, e, seu teor de umidade deve ser de no máximo 5,0% (BRASIL, 2018).

O leite em pó, por possuir baixa atividade de água, é considerado um produto estável em termos microbiológicos. Apesar do alto custo energético do processo de secagem, tem-se como outras vantagens o transporte do produto que não necessita de refrigeração e é facilitado devido à redução considerável de volume. Como basicamente somente a água é retirada do produto, a redução de volume não altera a composição do extrato seco do leite e facilita, ainda, o manuseio e o armazenamento. Além disso, há uma enorme demanda de leite em pó como ingrediente para diversos produtos, como biscoitos, massas, farinhas, sorvetes e diversos outros alimentos lácteos (MEDEIROS, 2010).

A produção mundial de leite em pó tem aumentando constantemente nos últimos anos devido a diversas comodidades trazidas pela sua fabricação, como: os elevados atributos de qualidade do produto, que pode ser mantido sem condições especiais de armazenamento preservando a funcionalidade, a segurança e suas propriedades tecno-funcionais para aplicação; a redução de volume, favorecendo etapas como transporte e estocagem; a possibilidade de oferta do produto por tempo superior ao produto fluido, a não exigência de embalagens complexas; a facilidade de reconstituição, entre outras. (SCHUCK *et al.*, 2016).

As etapas de processamento do leite em pó consistem em recepção, clarificação, resfriamento e armazenamento, padronização, tratamento térmico, evaporação, homogeneização, secagem e embalagem (FENELON *et al.*, 2021).

Características de reconstituição

O pó obtido pelo processo de secagem deve ser de fácil hidratação e reconstituição. Ao ser despejado sobre a superfície da água deverão ocorrer os seguintes fenômenos: (i) molhabilidade ou umectabilidade, que consiste na penetração do líquido para o interior da estrutura do pó, movido por forças capilares; (ii) imersibilidade, que é a imersão das partículas ou de porções do pó no líquido; (iii) dispersibilidade, ou seja, a capacidade do pó de se espalhar no líquido e a (iv) solubilidade, que é a dissolução das partículas pelo líquido, desde que estas sejam solúveis. O índice de insolubilidade de um pó é uma medida do grau em que pode ser prontamente solubilizado em água antes da utilização. Está relacionado com a quantidade de sedimento obtido sob condições definidas de mistura de pós de leite. A fluidez também é influenciada por outros fatores, como a gordura total no pó e a quantidade de gordura livre. As

propriedades associadas a essas quatro etapas são denominadas de “instantaneidade” do produto (PISECKY, 2012).

O leite em pó instantâneo visa atender consumidores que são exigentes quanto à praticidade e à qualidade do produto. Diversos fatores estão relacionados com a obtenção de leite em pó instantâneo, dentre os quais destacam-se gordura livre, densidade da partícula, aglomeração, intensidade do tratamento térmico, presença de lactose amorfa, retorno de finos para câmara de secagem, tipo de atomizador e equipamento de secagem empregado (SILVEIRA *et al.*, 2013).

Em relação à molhabilidade, existe uma correlação inversa entre esta e o conteúdo de gordura livre. Quando maior o teor de gordura livre mais difícil será a penetração do líquido pelas partículas, dificultando a hidratação (PISECKY, 2012).

Gordura livre, encapsulada e gordura superficial

A partícula de leite em pó é composta por gordura livre e encapsulada, a gordura livre é considerada como a gordura (i) que não é inteiramente revestido e estabilizado por moléculas anfífilas, por exemplo, pela membrana nativa do glóbulo de gordura, composta por fosfolipídios e proteínas ou por um revestimento reconstituído de proteínas adsorvidas após alguns passos de processamento, tais como tratamento térmico e homogeneização, ou (ii) que não é totalmente protegido por uma matriz composta por carboidratos amorfos (por exemplo, lactose) e proteínas durante a secagem. Essa gordura está localizada tanto na superfície quanto nas partes internas de uma partícula do pó (VIGNOLLES *et al.*, 2007).

As frações de gordura livre apresentam concentrações levemente mais altas de ácidos graxos saturados C6-C18 e concentrações ligeiramente menores de ácidos graxos

insaturados C16-C18 em comparação com a gordura total. Apresentam maior proporção de triacilgliceróis de alto ponto de fusão do que a gordura encapsulada. Os triacilgliceróis de alto ponto de fusão presentes nas frações de gordura livre são levemente acumuladas na superfície do pó (KIM *et al.*, 2005a). Entretanto, a gordura encapsulada representa cerca de 90% da gordura total (VIGNOLLES *et al.*, 2007).

A gordura livre pode ser também definida como a fração de gordura que é extraída por solventes orgânicos sob condições padronizadas, sendo um aspecto importante para caracterizar os pós lácteos que contêm gordura. O tempo, o solvente e a técnica delimitam qual fração da gordura será extraída, frações internas e encapsuladas são extraídas consideravelmente de forma mais lenta (KIM *et al.*, 2005a). Acredita-se que a gordura livre esteja presente principalmente (e, portanto, extraída) na superfície do pó (VIGNOLLES *et al.*, 2007).

Nem toda gordura presente na superfície estará na forma livre, uma parte dela será encapsulada. A quantidade total de gordura superficial livre, frequentemente expressa pela eficiência de encapsulação de uma amostra de pó, é frequentemente quantificada pela extração de gordura superficial. Contudo, nenhum procedimento padrão foi estabelecido e as técnicas na literatura variam consideravelmente entre si, conforme resumido por Vega; Roos (2006). A quantidade de gordura extraída depende ainda do tamanho e da porosidade da partícula (VIGNOLLES *et al.*, 2007).

Acredita-se que uma quantidade significativa de gordura extraível não se origine das superfícies das partículas, mas da gordura livre interna que é extraída do interior das partículas através de poros e fissuras, em particular em misturas relativamente intensas e longos tempos de exposição ao solvente (SCHMIDMEIER *et al.*, 2019; BUCHHEIM,

1982). Por essa razão, os resultados da extração de gordura das amostras de leite em pó podem, na maioria das vezes, representar a quantidade de gordura livre em vez da quantidade de gordura da superfície livre (KIM *et al.*, 2005b).

Nesse sentido, para caracterizar amostras de pós quanto à gordura superficial, comumente utiliza-se análise espectroscópica de fotoelétrons de raios X (XPS), também referida como espectroscopia de elétrons para análise química, neste contexto é o método predominante para quantificar a composição química superficial de partículas de leite (GAIANI *et al.*, 2010; MURRIETA-PAZOS *et al.*, 2012; WU *et al.*, 2014; NIKOLOVA *et al.*, 2014; NIKOLOVA *et al.*, 2015; KELLY *et al.*, 2015). Nesta técnica de análise de superfície sensível, as amostras de pó são irradiadas com um feixe de raios X de um nível de energia bem definido sob alto vácuo, e elétrons são emitidos se sua energia de ligação for ultrapassada pela energia do fóton (FOERSTER *et al.*, 2017b).

Apesar da técnica não detectar a gordura livre, ela é capaz de determinar a composição superficial do pó, que geralmente é rica por lipídeos. Como grande parte da gordura se acumula na superfície, consequentemente junto a ela estará a gordura livre. É de grande importância medir adequadamente a composição superficial de pós lácteos, a fim de prever suas propriedades de uso, pois quanto maior o teor de gordura na superfície maior será o teor de gordura livre e pior será a qualidade do pó (VIGNOLLES *et al.*, 2007).

Na maioria dos casos, gordura livre é considerado um defeito. A exceção é onde gordura livre é necessária para uma aplicação específica, por exemplo, fabricação de chocolate. Uma das influências mais críticas da 'gordura livre' é o teor de umidade do pó. Se a umidade for muito baixa (< 2,5%), a gordura livre aumenta e diminui à medida que o teor de umidade aumenta de 2,5% para 4% a 5%,

mas aumenta novamente se o teor de umidade for superior a 6% a 7% (LI *et al.*, 2019).

GORDURA SUPERFICIAL EM LÁCTEOS DESIDRATADOS

Aspectos indesejáveis

A camada hidrofóbica, formada devido ao acúmulo de gordura, torna as partículas de pó hidrofóbicas, dificultando a hidratação do pó, e, além disso, a gordura livre na superfície é um fácil alvo para a oxidação, podendo levar o produto a rancidez hidrolítica, aumento de viscosidade, redução das características de reconstituição (molhabilidade, penetrabilidade, dispersibilidade e solubilidade) e perda de qualidade do produto, dentre outros (PISECKY, 2012; VEGA; ROOS, 2006; KIM *et al.*, 2005a; KIM *et al.*, 2005b; NIJDAM; LANGRISH, 2006).

A segregação de componentes do leite em pó é sistematicamente observada entre a superfície e o núcleo, onde a gordura migra preferencialmente para a superfície afetando fortemente as propriedades do pó (NIKOLOVA *et al.*, 2015). O acúmulo de gordura na superfície do pó não é desejado, atribuindo ao produto algumas características indesejáveis, como dificuldade de reconstituição, aumento da taxa de oxidação de lipídios, aumento da viscosidade, perdas do produto, entre outros (KIM *et al.*, 2005a; KIM *et al.*, 2005b; VIGNOLLES *et al.*, 2007; KIM *et al.*, 2009; GAIANI *et al.*, 2010; MURRIETA-PAZOS *et al.*, 2012).

Ocorrências sobre acúmulo de gordura superficial

O acúmulo de gordura na superfície tem sido documentado por diversos estudos (GAIANI *et al.*, 2010; MURRIETA-PAZOS *et al.*, 2012; WU *et al.*, 2014; NIKOLOVA *et al.*, 2014; NIKOLOVA *et al.*, 2015; KELLY *et*

al., 2015) trazendo consequências negativas para qualidade do pó.

KIM *et al.* (2005a) investigaram a composição em massa e a composição superficial de pós lácteos (Tabela 1).

Como pode ser observado pela Tabela 1, à medida que o teor de gordura do pó aumenta, há um aumento acentuado na cobertura de gordura da superfície. O leite em pó integral com composição de 29% de gordura em massa apresentou uma cobertura superficial de 98% de gordura, ou seja, praticamente toda a superfície foi formada por gordura. Mesmo para lácteos com teor muito baixo de gordura, como leite em pó desnatado, por exemplo, com apenas 1% de gordura, sua superfície era constituída por 18% de gordura (KIM *et al.*, 2005a). O comportamento de escoamento dos pós também foi verificado, e o pó com menor teor de gordura superficial, o leite em pó desnatado, pode fluir mais facilmente que os demais. A gordura na superfície dos pós tem tendência a fazer com que as partículas se colem umas às outras ou se aglomerem, diminuindo a fluidez deles (KIM *et al.*, 2005a).

Mesmo para pós com baixo teor de gordura como fosfato nativo, é possível observar sobreposição de gordura na superfície dos mesmos, fosfato nativo possuindo apenas 0,4% de lipídios em massa, possuiu 6% de

gordura em sua superfície. Após 30 dias de armazenado houve aumento do teor de gordura na superfície sendo encontrados valores de 13% de gordura e após 60 dias o teor de gordura superficial foi de 17%, evidenciando migração desta para a superfície durante a etapa de armazenamento (GAIANI *et al.*, 2010).

Outros estudos têm também relatado que a gordura tende a se sobrepor na superfície da partícula em comparação com a composição da massa (KIM *et al.*, 2005a; KIM *et al.*, 2009; GAIANI *et al.*, 2010; FYFE *et al.*, 2011; FOERSTER *et al.*, 2016a; FOERSTER *et al.*, 2017a). Emulsões de leite (modelo) com teor de gordura similar ao leite integral, após secas, apresentaram em suas superfícies mais de 80% de gordura (KIM *et al.*, 2005; MURRIETA-PAZOS *et al.*, 2012; FOERSTER *et al.*, 2016b; FOERSTER *et al.*, 2017a), teor de gordura quase três vezes maior em relação à composição em massa. Emulsões modelo de leite desnatado e concentrados de proteína do leite também obtiveram acúmulo de gordura na superfície do pó com 3,5% e 45,9% de gordura superficial para conteúdo de gordura de 0,6% e 1,5% em massa, respectivamente, sobreposição de gordura de 6 a 30 vezes em comparação com a composição em massa (KIM *et al.*, 2009; FYFE *et al.*, 2011;

Tabela 1 – Composição em massa e composição superficial dos pós industriais lácteos secos* por pulverização (assumindo que os pós lácteos são compostos por três componentes principais: lactose, proteína e gordura)

Produtos	Composição em massa (%)			Composição da superfície (%)		
	Lactose	Proteína	Gordura	Lactose	Proteína	Gordura
LPD	58	41	1	36	46	18
LPI	40	31	29	2	-	98
CLP	13	12	75	1	-	99
WPC	8	86	6	6	41	53

* LPD: Leite em pó desnatado; LPI: Leite em pó integral; CLP: Creme de leite em pó, WPC: *Whey protein concentrate*.

Fonte: adaptado de KIM *et al.*, 2005a.

MURRIETA-PAZOS *et al.*, 2012; NIKOLOVA *et al.*, 2014; KELLY *et al.*, 2015).

Processos de acúmulo de gordura

Uma das técnicas de secagem mais utilizadas para lácteos desidratados é a por atomização, também conhecida como *spray drying*. O leite concentrado é pulverizado em pequenas gotículas na câmara de secagem que em contato com uma corrente de ar quente e seco, seca-se instantaneamente devido à diferença de temperatura e pressão parcial de vapor entre o ar e a gotícula (PERRONE *et al.*, 2016). O processo de secagem faz com que ocorram modificações estruturais e físico-químicas no leite, que por sua vez influenciará a reconstituição e propriedades de manuseamento dos pós (CARVALHO *et al.*, 2020).

A migração de componentes do leite ocorre tanto durante a atomização (WU *et al.*, 2014; FOERSTER *et al.*, 2016a; FOERSTER *et al.*, 2017a) quanto durante a secagem (ADHIKARI *et al.*, 2009; GAIANI *et al.*, 2010; FU *et al.*, 2011; NIKOLOVA *et al.*, 2014; WU *et al.*, 2014; KELLY *et al.*, 2015). Durante ambos os processos, as gorduras se acumulam preferencialmente na superfície das gotículas de leite, levando a uma cobertura de gordura dominante no leite em pó (KIM *et al.*, 2009; FU *et al.*, 2011; FOERSTER *et al.*, 2017a).

Os principais fatores que foram estudados como causadores da segregação durante a secagem, onde as gotículas entram em contato com o ar quente, foram a difusividade, atividade de superfície, hidrofobicidade dos componentes e formação de crosta (ADHIKARI *et al.*, 2009; GAIANI *et al.*, 2010; FU *et al.*, 2011; NIKOLOVA *et al.*, 2014; WU *et al.*, 2014; KELLY *et al.*, 2015).

No caso da atomização propõe-se que durante esse estágio, um mecanismo de desintegração ao longo da interface

óleo-água dos glóbulos de gordura cause a predominância superficial da gordura (FOERSTER *et al.*; 2016a, FOERSTER *et al.*, 2017a).

O teor de gordura superficial não é significativamente redutível modificando as condições de secagem por pulverização, já que grande parte da gordura se acumula na superfície dos pós durante a etapa de atomização. Pelo motivo exposto, uma forma promissora de reduzir a quantidade de gordura superficial é modificar a emulsão antes da secagem por pulverização, para moderar a segregação entre o lipídio e a fase aquosa durante a atomização (FOERSTER *et al.*, 2016a; FOERSTER *et al.*, 2017a).

PROCESSOS DE ESTABILIZAÇÃO

Lecitinação

A lecitina tem propriedades hidrofílicas e lipofílicas e pode ser utilizada para recobrir a superfície das partículas do leite em pó, pois suas características anfílicas permitem que elas sejam adsorvidas na interface gordura/ água, com a porção hidrofílica na fase aquosa e a porção lipofílica na fase oleosa. O resultado é um revestimento em torno da superfície das partículas de leite em pó (contendo gordura) aumentando a sua afinidade pela água servindo literalmente de ponte entre a gordura e a água e facilitando, assim, a dispersão do pó (PISECKY, 2012). O teor máximo permitido no Brasil de lecitina para leite em pó instantâneo é de 5g/ kg (BRASIL, 2018).

Aglomerção

A aglomeração em leiteo fluidizado é utilizada para produzir aglomerados secos, grandes e porosos com propriedades instantâneas melhoradas. É um processo de transformação do material do estado do pó

para o estado de grânulos com estrutura porosa permitindo melhorias na reconstituição do leite em pó. As partículas de pó secas por atomização são umidificadas, inchando rapidamente e fechando os capilares, de modo que suas superfícies se tornem pegajosas e se colem umas às outras para formar aglomerados/ conglomerados (BARKOUTI *et al.*, 2013). As propriedades de reidratação (por exemplo, molhabilidade, capacidade de escoamento, dispensibilidade, solubilidade e taxa de dissolução) são aprimoradas. Em grandes indústrias são as etapas de aglomeração e lecitinação que dão ao leite em pó seu caráter instantâneo, por meio de uma unidade de leite fluidizado adicionada ao final da linha de secagem por pulverização (GAIANI *et al.*, 2010).

Adição de estabilizantes à emulsão

Uma forma de reduzir o teor de gordura livre pode ser pela estabilização da emulsão antes dela passar pelo processo de secagem, que consiste no encapsulamento eficiente da gordura (FOERSTER *et al.*, 2017a). Isso pode ser feito pela adição de agentes interfaciais, como surfactantes, polissacarídeos, e outros agentes interfaciais antes do processo de atomização (XU *et al.*, 2013; LALLBEEHARRY *et al.*, 2014; FOERSTER *et al.*, 2017a).

Para emulsões lácteas a adição de agentes interfaciais pode ser de grande interesse, entretanto tratando-se de leite em pó, como aditivo, somente é permitido o uso da lecitina, no teor máximo de 5g/ kg para leite em pó instantâneo (BRASIL, 2018). Portanto a estabilização com outros compostos não é possível.

Redução do tamanho do glóbulo de gordura por homogeneização

Uma forma de reduzir a ocorrência

de gordura livre na superfície do pó é a homogeneização com pressões mais altas que as convencionais. Havendo por esse processo maior redução do tamanho dos glóbulos de gordura e melhor encapsulamento desses glóbulos, tornando a emulsão mais estável e possivelmente com menor ocorrência de gordura livre na superfície do pó. A pressão de homogeneização mais comumente utilizada nas indústrias é em torno de 20 MPa. No entanto, com o desenvolvimento de projetos de homogeneizadores, os processos de homogeneização podem atingir pressões muito mais elevadas, como 350 MPa, (MERCAN *et al.*, 2018) o que permite novas pesquisas, desenvolvimento de produtos e área de aplicações.

Durante a homogeneização há deformação e quebra de gotículas de gordura líquida, formando gotículas menores que são rapidamente adsorvidas pelo surfactante, que no caso do leite são suas proteínas, que são capazes de ajudar na separação das gotículas durante a homogeneização e prevenção da coalescência das gotículas de óleo (FENNEMA *et al.*, 2017). As proteínas do leite adsorvidas aos glóbulos de gordura são responsáveis por promover repulsão eletrostática entre as gotículas e também promover estabilização estérica (VIGNOLLES *et al.*, 2007).

Dependendo da pressão diferencial utilizada no processo de homogeneização, o fluido apresenta grande cisalhamento, cavitação e turbulência, e esses efeitos mecânicos são utilizados para mistura, dispersão, redução do tamanho de partículas e emulsificação. A adsorção de proteínas e a coalescência ocorrem em escalas de tempo curtas e a faixa final de tamanho de gotas da dispersão coloidal e sua estabilidade é governada pela entrada de energia mecânica, tipo e concentração do estabilizador e proporção de emulsificante para estabilizador (LEE *et al.*, 2013).

CONSIDERAÇÕES FINAIS

O leite e produtos lácteos em pó apresentam maior vida de prateleira, viabilizando ganhos econômicos no armazenamento e transporte, enquanto o leite *in natura* é altamente perecível e volumoso, exigindo embalagem, estocagem e transporte especiais. Entretanto, a ocorrência de gordura na superfície de pós lácteos, tanto gordura livre como gordura encapsulada, tem sido vastamente documentada junto com problemas tecnológicos que também estão atrelados a essas características como maior taxa de oxidação, maior viscosidade, dificuldades de reidratação e outros.

Leites em pós integrais podem apresentar mais de 80% de gordura em sua composição superficial e para leites ou lácteos em pós, este com teor reduzido de gordura, ainda assim se observa predominância desse componente na superfície, diferindo bastante da composição em massa. As etapas mais críticas para esse acúmulo de gordura são as etapas de atomização e secagem. Muitas indústrias já usam as etapas de aglomeração e lecitinação para reduzir os efeitos indesejáveis da gordura superficial.

Outras propostas para menor ocorrência de gordura livre na superfície estão atreladas a melhor estabilização da emulsão antes do processo de secagem por atomização. Como no Brasil a adição de componentes no leite em pó não é permitida, salvo os especificados em regulamento, uma das ideias promissoras é tentar estabilizar a emulsão com a utilização da ultra alta homogeneização. Estudos sistemáticos sobre o papel da alta pressão durante a emulsificação da gordura são escassos, podendo ser uma nova linha de pesquisa a ser estudada.

AGRADECIMENTOS

Os autores agradecem ao CNPq pelas

bolsas de produtividade e pelos investimentos em pesquisas.

REFERÊNCIAS

- ADHIKARI, B. *et al.* Effect of addition of proteins on the production of amorphous sucrose powder through spray drying. **Journal of Food Engineering**, v. 94, n. 2, p. 144-153, 2009. DOI: 10.1016/j.jfoodeng.2009.01.029.
- BARKOUTI, A. *et al.* Milk powder agglomerate growth and properties in fluidized bed agglomeration. **Dairy Science and Technology**, v. 93, n. 4-5, p. 523-535, 2013. DOI: 10.1007/s13594-013-0132-7.
- BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa nº 53, de 1º de outubro de 2018. Regulamento Técnico Mercosul de Identidade e Qualidade do Leite em Pó. **Diário Oficial da União**: seção 1, Brasília, DF, n. 199, p. 11, 16 out. 2018.
- BUCHHEIM, W. Electron microscopic localization of solvent-extractable fat in agglomerated spray-dried whole milk powder particles. **Food Structure**, v. 1, n. 2, Article 12, 1982.
- CARVALHO *et al.* (org.). **Química e Tecnologia do Soro de Leite**. 1ª ed. Juiz de Fora: Innóvite, 2020.
- FENELON, M. A. *et al.* Innovations and prospects. In: FLOCH-FOUÉRÉ, C. *et al.* (org.). **Drying in the Dairy Industry: From Established Technologies to Advanced Innovations**. 1ª ed. Boca Raton: CRC Press, 2021.
- FENNEMA, O. R.; DAMODARAN, S.; PARKIN, K. L. Introduction to food chemistry. In: DAMODARAN, S.; PARKIN, K. L. (ed.). **Fennema's Food Chemistry**. 5ª ed. Boca Raton: CRC Press, 2017.

- FOERSTER, M. *et al.* The impact of atomization on the surface composition of spray-dried milk droplets. **Colloids and Surfaces B: Biointerfaces**, v. 140, p. 460-471, 2016a. DOI: 10.1016/j.colsurfb.2016.01.012.
- FOERSTER, M. *et al.* The influence of the chemical surface composition on the drying process of milk droplets. **Advanced Powder Technology**, v. 27, n. 6, p. 2324-2334, 2016b. DOI: 10.1016/J.APT.2016.07.004.
- FOERSTER, M. *et al.* Reduction of surface fat formation on spray-dried milk powders through emulsion stabilization with λ -carrageenan. **Food Hydrocolloids**, v. 70, p. 163-180, 2017a. DOI: 10.1016/j.foodhyd.2017.04.005.
- FOERSTER, M.; WOO, M. W.; SELOMULYA, C. Component segregation during spray drying of milk powder. In: VARELIS, P.; MELTON, L.; SHAHIDI, F. **Encyclopedia of Food Chemistry**. Amsterdam: Elsevier, 2017b.
- FU, N.; WOO, M. W.; CHEN, X. D. Colloidal transport phenomena of milk components during convective droplet drying. **Colloids and Surfaces B: Biointerfaces**, v. 87, n. 2, p. 255-266, 2011. DOI: 10.1016/j.colsurfb.2011.05.026.
- FYFE, K. *et al.* Influence of dryer type on surface characteristics of milk powders. **Drying Technology**, v. 29, n. 7, p. 758-769, 2011. DOI: 10.1080/07373937.2010.538481.
- GAIANI, C. *et al.* How surface composition of high milk proteins powders is influenced by spray-drying temperature. **Colloids and Surfaces B: Biointerfaces**, v. 75, n. 1, p. 377-384, 2010. DOI: 10.1016/j.colsurfb.2009.09.016.
- KELLY, G. M. *et al.* Influence of protein concentration on surface composition and physico-chemical properties of spray-dried milk protein concentrate powders. **International Dairy Journal**, v. 51, p. 34-40, 2015. DOI: 10.1016/j.idairyj.2015.07.001.
- KIM, E. H. J.; CHEN, X. D.; PEARCE, D. Surface composition of industrial spray-dried milk powders. 2. Effects of spray drying conditions on the surface composition. **Journal of Food Engineering**, v. 94, n. 2, p. 169-181, 2009. DOI: 10.1016/j.jfoodeng.2008.10.020.
- KIM, E. H. J.; CHEN, X. D.; PEARCE, D. Effect of surface composition on the flowability of industrial spray-dried dairy powders. **Colloids and Surfaces B: Biointerfaces**, v. 46, n. 3, p. 182-187, 2005b. DOI: 10.1016/j.colsurfb.2005.11.005.
- KIM, E. H. J.; DONG, X.; PEARCE, D. Melting characteristics of fat present on the surface of industrial spray-dried dairy powders. **Colloids and Surfaces B: Biointerfaces**, v. 42, p. 1-8, 2005a. DOI: 10.1016/j.colsurfb.2005.01.004.
- LALLBEEHARRY, P. *et al.* Effects of ionic and nonionic surfactants on milk shell wettability during co-spray-drying of whole milk particles. **Journal of Dairy Science**, v. 97, n. 9, p. 5303-5314, 2014. DOI: 10.3168/jds.2013-7772.
- LEE, L. L. *et al.* Emulsification: Mechanistic understanding. **Trends in Food Science and Technology**, v. 31, n. 1, p. 72-78, 2013. DOI: 10.1016/j.tifs.2012.08.006.
- LI, Y. H. *et al.* Comparative study on the characteristics and oxidation stability of commercial milk powder during storage. **Journal of Dairy Science**, v. 102, n. 10, p. 8785-8797, 2019. DOI: /10.3168/jds.2018-16089.
- MEDEIROS, U. K. L. **Viabilidade técnica de uma rota não convencional para a produção de leite de cabra em pó em**

- cooperativas do Rio Grande do Norte.** 2010. 189 f. Tese (Doutorado em Pesquisa e Desenvolvimento de Tecnologias Regionais) – Universidade Federal do Rio Grande do Norte, Natal, 2010.
- MERCAN, E.; SERT, D.; AKIN, N. Determination of powder flow properties of skim milk powder produced from high-pressure homogenization treated milk concentrates during storage. **LWT Food Science and Technology**, v. 97, p. 279-288, 2018. DOI: 10.1016/j.lwt.2018.07.002.
- MUNIZ, L. C. *et al.* Consumo de leite e derivados entre adultos e idosos no sul do Brasil: Um estudo de base populacional. **Ciência & Saúde Coletiva**, v. 18, p. 3515-3522, 2013.
- MURRIETA-PAZOS, I. *et al.* Composition gradient from surface to core in dairy powders: Agglomeration effect. **Food Hydrocolloids**, v. 26, n. 1, p. 149-158, 2012. DOI: 10.1016/j.foodhyd.2011.05.003.
- NIJDAM, J. J.; LANGRISH, T. A. G. The effect of surface composition on the functional properties of milk powders. **Journal of Food Engineering**, v. 77, n. 4, p. 919-925, 2006. DOI: 10.1016/j.jfoodeng.2005.08.020.
- NIKOLOVA, Y. *et al.* Is it possible to modulate the structure of skim milk particle through drying process and parameters? **Journal of Food Engineering**, v. 142, p. 179-189, 2014.
- NIKOLOVA, Y. *et al.* Toward a better determination of dairy powders surface composition through XPS matrices development. **Colloids and Surfaces B: Biointerfaces**, v. 125, p. 12-20, 2015. DOI: 10.1016/j.colsurfb.2014.11.009.
- PERRONE, I. T. *et al.* Uso de ferramentas matemáticas em processos de secagem de leite e soro. **Indústria de Laticínios**, v. 123, p. 68-70, 2016.
- PISECKY, J. **Handbook of Milk Powder Manufacture.** 2^a ed. Copenhagen: GEA Process Engineering, 2012.
- SCHMIDMEIER, C. *et al.* Elucidation of factors responsible for formation of white flecks in reconstituted fat filled milk powders. **Colloids and Surfaces A: Physicochemical and Engineering Aspects**, v. 575, p. 245-255, 2019. DOI: 10.1016/j.colsurfa.2019.03.034.
- SCHUCK, P. *et al.* Recent advances in spray drying relevant to the dairy industry: A comprehensive critical review. **Drying Technology**, v. 34, p. 1773-1790, 2016.
- SILVEIRA, A. C. P. *et al.* Secagem por spray drying: Uma revisão. **Revista do Instituto de Laticínios Cândido Tostes**, v. 68, n. 391, p. 51-58, 2013.
- VEGA, C.; ROOS, Y. H. Invited review: Spray-dried dairy and dairy-like emulsions – compositional considerations. **Journal of Dairy Science**, v. 89, n. 2, p. 383-401, 2006. DOI: 10.3168/jds.S0022-0302(06)72103-8.
- VIGNOLLES, M. L. *et al.* Free fat, surface fat and dairy powders: interactions between process and product – A review. **Le Lait**, v. 87, n. 3, p. 187-236, 2007.
- XU, Y. Y. *et al.* Effects of emulsification of fat on the surface tension of protein solutions and surface properties of the resultant spray-dried particles. **Drying Technology**, v. 31, n. 16, p. 1939-1950, 2013. DOI: 10.1080/07373937.2013.802331.
- WU, W. D. *et al.* Towards spray drying of high solids dairy liquid: Effects of feed solid content on particle structure and functionality. **Journal of Food Engineering**, v. 123, p. 130-135, 2014. DOI: 10.1016/j.jfoodeng.2013.05.013.

4. CONCLUSÕES GERAIS

O iogurte, assim como outros produtos lácteos, foi alvo de redução de açúcar nos últimos anos, levando indústrias a se adequarem a padrões exigidos pelo governo, órgãos de saúde e consumidores. Apesar da diminuição de açúcar ter um impacto direto nas características sensoriais do produto foi possível demonstrar que reduções que se enquadrem as normas exigidas podem ser aplicadas sem afetar a aceitação sensorial, e mesmo quando a redução vier a afetar a aceitação de seus consumidores a inclusão de informações no rótulo pode vir a tornar uma amostra comprometida em uma amostra igualmente aceita ao produto padrão.

Este foi o primeiro estudo em lácteos com a utilização da LMH para a redução de sacarose e os resultados aqui encontrados podem ajudar diversos fabricantes de lácteos a reduzirem esse ingrediente em seus produtos sem afetar a aceitação sensorial e ainda se enquadrarem nas metas estabelecidas. Mesmo para os casos em que ainda não há imposições de redução de açúcar, mostra-se interessante estudar seus efeitos, pois as indústrias que já tiverem verificado o impacto dessa redução e investigados os limites máximos a serem realizados estarão à frente das demais quando essas exigências forem regulamentadas e a tendência é que seja. Com o pleno vigor da RDC 429, e a implementação da nova rotulagem nutricional frontal, presume-se que o consumo de alimentos ricos em nutrientes potencialmente prejudiciais a saúde caia drasticamente, ao passo que alimentos reduzidos ou isentos em açúcares, como iogurtes com redução de sacarose, tenham cada vez mais visibilidade e atratividade no mercado.

Outra demanda existente é pela melhoria da qualidade do produto lácteo leite em pó. Pois durante a sua fabricação, o leite é submetido a uma série de processos como agitação, bombeamento, aquecimento, concentração, homogeneização e secagem por pulverização, esses tratamentos causam uma série de interações físicas e químicas dos componentes do leite e no final do processo a superfície das partículas geradas apresentam alto teor de gordura em sua composição, diferindo bastante da composição em massa. Esse acúmulo de gordura superficial, sendo composta por frações de gordura livre leva a efeitos prejudiciais nas propriedades do pó, incluindo solubilidade reduzida na água, oxidação de lipídios, aumento de viscosidade e consequentemente perda da qualidade do produto. As etapas mais críticas para esse acúmulo de gordura são as etapas de atomização e secagem. Nesta revisão, os aspectos sobre o leite em pó, geração da gordura superficial foram elucidados. Conclui-se que obter a capacidade de controlar a composição da superfície seria muito útil na melhoria da qualidade do produto e no

desenvolvimento de novos produtos e dentre as alternativas destaca-se a estabilização da emulsão antes do processo de secagem por atomização.