

Perception and knowledge of low- and no-calorie sweeteners in multidisciplinary stakeholders from Spain

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Abstract

Low- and no-calorie sweeteners (LNCS) as a category are one of the most thoroughly evaluated additives, and thus their safety has been largely recognised. However, their potential risks and benefits generate great controversy and discussion within countries' food policies and public debate. The goal of this study was to evaluate the degree of knowledge and the perception of key Spanish stakeholders about the role of LNCS in diet, their safety, regulatory issues and their impact on health and wellness, as well as to complete a SWOT analysis of the Strengths, Weaknesses, Opportunities and Threats regarding this topic from their perspective. Participants ($n = 45$ stakeholders) completed an anonymous survey about their knowledge and perception of LNCS, their role in the diet, safety and legislation, as well as health issues and completed a SWOT analysis. Most of them agreed with aspects related to safety guarantees and authorisation procedure of LNCS; however, certain disparity in their opinion in relation to several of the topics was observed, especially regarding the possible role of LNCS in diet quality and health. Effective communication strategies to inform professionals and the general population, as well as new research that deepens our knowledge of the role of LNCS in weight management and other health outcomes seem to be urgently needed.

KEYWORDS

added sugars, additives, food policy, food reformulation, food safety, low- and no-calorie sweeteners

INTRODUCTION

Low and/or no-calorie sweeteners (LNCS) are a chemically heterogeneous group of food additives, comprising natural and artificial compounds, that when added to foods are intended to deliver different degrees of sweetness but provide considerably less energy (Chattopadhyay et al., 2014; European Union, 2010). LNCS are also referred to as artificial sweeteners,

non-nutritive sweeteners, high-intensity sweeteners and non-caloric sweeteners. Currently, 19 LNCS are authorised in Europe (European Union, 2010), which are added to a variety of foods and beverages instead of sugar either during the manufacturing process or as table-top sweeteners. Specifically, seven of them are classified as polyols (low-calorie sweeteners) and the remaining 12 as non-calorie sweeteners (European Union, 2011). Current authorised LNCS are shown in

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Table 1 (European Union, 2011). In addition, some of them are used by the food industry due to other suitable technological properties (as stabilisers, texturisers, etc.). The interest in and use of LNCS has greatly increased over the last 20 years, given that they provide an interesting opportunity to reduce sugar intake and, consequently, the caloric content of the diet (Olivier et al., 2015). This is important for weight management (Wilk et al., 2022) and associated conditions (Popkin & Hawkes, 2016). Therefore, the use of LNCS as a replacement for sugar could constitute a public health policy for disease prevention in the context of a healthy diet and lifestyle (Gardner et al., 2012; Malik, 2019). Moreover, these compounds are under the scope of food policies in different countries. In fact, different institutions, such as the European Food Safety Authority (EFSA; European Union European Parliament and Council Directive, 1994; The European Commission's Science and Knowledge Service, 2022), the American Heart Association (Gardner et al., 2012), the American Diabetes Association (Gardner et al., 2012) and the Academy of Nutrition and Dietetics (Fitch & Keim, 2012), among others, have given their approval to the consumption of LNCS and have recommended them in the context of structured nutrition programmes, in which the compensatory increment of energy intake provided by other sources is limited. Nevertheless, the scientific evidence in this regard has been questioned, and data are still insufficient to determine any long-term

nutritional benefits related to the consumption of products containing LNCS as sugar substitutes (Olivier et al., 2015). In fact, at present, no claim related to the effects of LNCS on weight management has been authorised by EFSA (EFSA Panel on Dietetic Products, Nutrition, & Allergies, 2011).

All authorised LNCS have undergone an extensive safety evaluation process by international and national regulatory food safety institutions, both before and after their approval, including the Technical Commission on Food Additives and Flavours of EFSA (European Union, 2011), the Food and Agriculture Organization (FAO)/World Health Organization (WHO), the Joint Expert Committee on Food Additives (JECFA; Malik, 2019), and the US Food and Drug Administration (FDA; Norte Navarro & Ortiz Moncada, 2011), which confirmed the safety of these LNCS as food additives. In addition, there is an on-going review process to evaluate any new information on their safety (Aguilar et al., 2017; EFSA ANS Panel (EFSA Panel on Food Additives and Nutrient Sources added to Food), 2013). However, LNCS are often associated with a wide range of adverse health outcomes, such as their potential role in modifying food preferences or mood and causing abdominal obesity, diabetes, neurodegenerative diseases or dementia, carcinogenicity and/or gut microbiota alterations, among others (Samaniego Vaesken et al., 2021). However, at present, the evidence available for these outcomes is still inconsistent or emerging (Lohner et al., 2017). The WHO recently published a systematic review and meta-analysis on the health effects of non-sugar sweeteners which found that cohort studies generally show an increased risk of cardiometabolic diseases and all-cause mortality associated with non-sugar sweeteners although the evidence was graded as having very low to low certainty (Rios-Leyvraz et al., 2022). Therefore, more studies are urgently needed to rule out potential long-term risks related to LNCS consumption in specific populations, such as daily consumers, pregnant women, children or people with diabetes (Olivier et al., 2015). In this regard, several reviews concluded that little high-quality clinical research has been undertaken to identify the potential risks and benefits of LNCS (García-Almeida et al., 2013; Olivier et al., 2015; Wiebe et al., 2011). Furthermore, researchers also concluded that it is difficult to distinguish between the effects of the various LNCS consumed alone and their effects when combined with other LNCS. All of the above lead to difficulties in adopting food policies by different countries within the public health nutrition context. At present, the potential risks and benefits linked to the consumption of LNCS generate controversy, not only among consumers, but also among the scientific community, health professionals and those responsible for formulating food products and nutrition policies (Kroger et al., 2006; Malik, 2019). In fact, Spain implemented a plan to reduce the content of

TABLE 1 Current authorised low and/or no-calorie sweeteners (LNCS) in the European Union

Authorised LNCS in the European Union
Sorbitol (E-420)
Mannitol (E-412)
Acesulfame K (E-950)
Aspartame (E-951)
Cyclamate (E-952)
Isomalt (E-953)
Saccharine and its sodium, potassium and calcium salts (E-954)
Sucralose (E-955)
Thaumatococin (E-957)
Neohesperidine DC (E-959)
Steviol glycosides (E-960)
Neotame (E-961)
Salt of aspartame-acesulfame (E-962)
Polyglycolic syrup (E-964)
Maltitols (E-965)
Lactitol (E-966)
Xylitol (E-967)
Erythritol (E-968)
Advantame (E-969)

added sugars in food by the end of 2020, carried out by the Ministry of Consumer Affairs, through the Spanish Agency for Food Safety and Nutrition (AESAN) within the framework of the “Strategy for Nutrition, Physical Activity and Obesity Prevention” (NAOS; Ministerio de Sanidad Consumo y Bienestar Social, 2019) without mentioning LCNS specifically. In addition, several expert consensus have been recently held in order to share and deepen the current scientific knowledge about LNCS (Ashwell et al., 2020; Gibson et al., 2014; Serra-Majem et al., 2018). However, to date, very little is known about the opinion, perception and the level of knowledge of health and other involved professionals in this area and if they recommend, or not, the consumption of products that contain LCNS and their underlying reasons. In this regard, a recently published study (Aldrete-Velasco et al., 2020), investigating this topic in a Mexican population, surprisingly concluded that 31% of the professionals asked do not know the physico-chemical characteristics and metabolic effects of LNCS, in spite of it being a recurring topic in medical bibliography and public debate in this country.

For all the aforementioned reasons, we considered it of great interest to evaluate, for the first time, the degree of knowledge and perception of a group of Spanish stakeholders about the role of LNCS in the diet, their safety, regulatory issues and their impact on health and wellness, as well as to perform a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) regarding this topic.

METHODS

A convenience sample of Spanish stakeholders in the field of LNCS ($n = 84$), with at least 20 years of experience and leadership in their respective fields, were contacted and invited through email to participate in this study between October 2019 and January 2020. The sample included members from academia, researchers, members of the different government administrations, as well as managers and technical personnel in the field of the food industry, distribution and professional and consumer associations. Those who agreed to participate were asked to complete an anonymous survey designed in Microsoft™ Word format, comprising questions about their knowledge and perception of sweeteners, their role in the diet, safety and legislation, as well as health issues (Appendix S1). Stakeholders' responses were sent back by email to our research team for processing. The survey included 11 questions and a SWOT analysis in which participants were asked to cite one strength, one weakness, one opportunity and one threat of LNCS in their knowledge area and professional activity.

The survey included four answer options for each question (A, B, C and D), through which participants

expressed their degree of agreement with the statement (A: strongly agree, B: somewhat agree, C: somewhat disagree and D: strongly disagree). If participants answered the option C or D, they were additionally asked to describe their opinions/reasons in this regard. Finally, there were three questions in the survey with a different format: specifically questions 2, 8 and 9, which were dichotomous questions (answer: yes/no).

All the data collected in this survey were treated confidentially and according to the current data protection legislation. Likewise, only the personnel assigned to the project had blinded access to the data and no material will be published in which the participants could be identified. In any case, the study protocol agreed with the provisions of the General Data Protection Regulation of the European Union, RGDP UE 2016/976 and with the Personal Data Protection Act of 2018.

RESULTS

Sample characteristics

The overall response rate was 54%. Reasons of non-response were unknown except for one case, which was lack of time to complete the survey. Finally, 45 stakeholders were included in the study. The expertise areas to which the participants belonged to are represented in Figure 1 and a broad spectrum of professionals from the health and food sectors participated in the survey.

Results of the low and/or no-calorie sweeteners questionnaire

The responses obtained to questions 1–10 are represented in Tables 2 and 3, according to the question type.

As shown in Table 2, more than half of the stakeholders answered that they strongly agreed that LNCS have sufficient guarantees of safety (question 1). The main reasons declared by those disagreeing with the

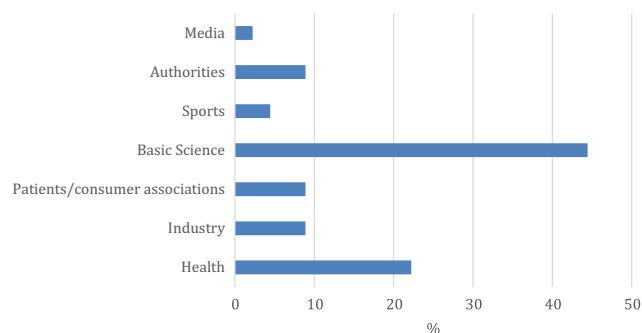


FIGURE 1 Knowledge areas of the stakeholders who participated in the study

TABLE 2 Results obtained from questionnaires, questions 1, 3–7 and 10–11

	A Strongly agree (%)	B Somewhat agree (%)	C Somewhat disagree (%)	D Strongly disagree (%)	No answer (%)
1. To what extent do foods containing low and/or no-calorie sweeteners (LNCS) provide you sufficient guarantees of safety?	67	24	9	0	0
3. According to EU labelling regulation, the presence of LNCS in food and beverages must be labelled twice (the name of the LNCS or the E-number must be included in the list of ingredients, and the term 'with sweetener(s)' must also be clearly stated together with the name of the food or beverage product). To what extent do you think that these data, as well as in the case of the rest of additives, is sufficient to inform consumers?	27	49	13	11	0
4. To what extent do you think that the consumption of LNCS or the intake of food containing LNCS could help to improve the overall quality of the diet?	24	36	36	4	0
5. To what extent do you think that the consumption of tabletop LNCS or the intake of food containing LNCS could help to improve body weight control?	20	56	24	0	0
6. To what extent do you think that LNCS consumption or the intake of food containing LNCS could help to improve risk factors in certain pathologies such as diabetes and other chronic conditions?	27	53	13	7	0
7. In the EU, since 2002, LNCS are validated and approved by the European Food Safety Authority (EFSA) and subsequently authorised by approval through food legislation by the European Commission of the Additive Regulation approved by European Parliament and the Council of Europe. To what extent do you think the authorization process is adequate?	62	29	5	0	4
10. To what extent do you consider that there is enough scientific evidence in your field of research and/or professional activity?	18	42	31	7	2
11. To what extent do you consider that the debate on the consumption of LNCS in the media and social networks is appropriate?	2	13	58	27	0

statement were: (1) lack of knowledge about the effects of LNCS in the digestive system, gut microbiota and the gut–brain axis regarding satiety signals, (2) shortfall of studies on admissible daily intake (ADI) as well as (3) lack of studies that support the benefits of LNCS in the human diet.

Concerning the knowledge of the 19 LNCS approved by the European Union (EU; Table 3), more than half of the participants claimed knowledge of them, despite the difficulty of remembering them individually. Furthermore, the stakeholders proposed several strategies to increase the knowledge about LNCS among health professionals and consumers. Those focused on health professionals included the creation of an official list of the approved LNCS, as

well as the development of a reliable and accessible database and conducting training sessions for professionals supported by materials and infographics. In addition, collaboration between EFSA and the International Association of Sweeteners or similar organisations to disseminate better knowledge of this issue was also recommended. Among the strategies targeted at consumers, it was proposed to increase knowledge about nutrition and dietetics, for example, by educational talks or awareness campaigns aimed at the general population, as well as for patients attending medical and nutrition counselling. Moreover, scientific television programmes aimed at consumers, media campaigns (television, internet and social networks) and information diffusion through

	Yes (%)	No (%)	No answer (%)
2. Do you know all LNCS approved in the European Union (EU)?	60	38	2
8. Regarding safety guarantees for LNCS, do you think that safety must be evaluated by the EU or by the by member countries by themselves? ^a	EU: 93	EU+Members: 5	2
9. From 2002, all scientific evidence of LNCS safety is evaluated, for its validation and approval, by the European Food Safety Authority (EFSA) and then LNCS are authorised, if applicable, by the regulatory institutions of the EU. Do you consider that, in addition to authorization process for LNCS safety, the scientific evidence to validate their benefits beyond their capabilities of technological properties should also be incorporated?	93	7	0

^aYes = EU, No = EU+Member states.

TABLE 3 Results obtained from the dichotomous questions (answer: yes/no) of the questionnaire (questions 2, 8 and 9)

infographics, posters or brochures at food outlets and in collaboration with local, regional and national Consumer Associations could be also considered.

Most of the stakeholders declared being somewhat in agreement with the way in which products that contain LNCS must be labelled in the EU (Table 2). Those in disagreement gave the following reasons: the information shown about the functionality of the additive is insufficient for the consumer and, in addition, owing to the small labelling font size, its content is not always understandable or legible for the general population. Moreover, the stakeholders suggested labelling should indicate the category to which additives belong, as well as the degree of safety and the maximum tolerable levels and the ADI. Lastly, they thought that despite labelling reporting the presence of additives, consumers are often unaware of their benefits, drawbacks and their possible health effects or consequences.

More than half of the stakeholders were strongly or somewhat in agreement with the statement: 'the consumption of LNCS or the intake of food containing LNCS could help to improve the overall quality of diet' (Table 2). In general, the main reasons reported by those disagreeing with this statement were the lack of conclusive or consistent research of their benefits in healthy populations, as well as the fact that diet quality is determined by dietary/nutritional habits but not because of the consumption of specific food ingredients.

Concerning the helpfulness of sweetener consumption in weight management, a large majority of participants (Table 2) were mostly in agreement with this statement. Among the reasons indicated by those disagreeing with the statement, it should be highlighted that, to date, the available systematic reviews have not yet obtained conclusive results and that weight loss

depends on several factors, not only on the consumption of an isolated product/ingredient. In addition, the stakeholders mentioned that the habituation to sweet taste, owing to LNCS consumption, could led to alterations in the threshold of sweetness perception and, thus, to an increase in sugar-containing foods consumption. Finally, it should be also considered that there are some foods that, despite containing LNCS, may have high energy density. Therefore, if the individual consumes large amounts of these foods, since they are considered less caloric, the energy reduction effect associated with LNCS could be compensated by the increase in the total amount of food consumed.

Regarding if the 'consumption of LNCS or the intake of foods containing LNCS could help to improve risk factors of certain pathologies such as diabetes or other chronic diseases', half the participants were somewhat in agreement with this statement (Table 2). Among the reasons given why stakeholders said they disagreed were: (1) no scientific evidence, according to the available literature, to confirm the improvement of pathology risk factors with LNCS intake, without changes in diet and lifestyle and (2) the origin of certain diseases is not only due to a single food risk factor, but the combination of several.

When evaluating the LNCS authorisation procedure a vast majority of the stakeholders agreed with it (Table 2). Nevertheless, a small proportion of participants declared that they somewhat disagreed with it since few analytical data about these types of sweeteners are available, which make recommendations on intakes difficult and complex to establish. Lastly, it is important to highlight that 4% of stakeholders did not answer this question due to their ignorance of this procedure or their lack of opinion about it.

TABLE 4 Summary of the results obtained in the SWOT (Strengths, Weakness, Opportunities and Threats) analysis

Strengths	Opportunities
<ul style="list-style-type: none"> Sweetening without increasing blood glucose or energy intake Usefulness in several pathologies or conditions Authorisation and surveillance system Safety evaluation Strong and harmonised legislation throughout the European Union Solid scientific evidence about low and/or no-calorie sweeteners (LNCS) and health 	<ul style="list-style-type: none"> Increased variety of products Design of healthier diets Development of nutritional strategies and spread of truthful information Growing concern related to the intake of added sugar, control of body weight and nutrition in general Inclusion in the dietary guidelines Reformulation and development of new products
Weaknesses	Threats
<ul style="list-style-type: none"> Modification of the organoleptic characteristics of foods Public opinion/perception due to their condition of being additives Risk of overcompensating for calories saved by using LNCS Generalisation of scientific knowledge under the concept of 'sweeteners' Complex legislation Lack of scientific studies in several areas in certain population groups Lack of information about real consumption 	<ul style="list-style-type: none"> Lack of knowledge in both healthcare professionals and general population Biased information spread to general population Conflict of interests with other sectors Current penalty about sweet food Lack of high-quality scientific studies Unavailability of databases that include the content of additives in food Consumption of excessive amounts

Next, stakeholders were asked if safety guarantees for LNCS should be evaluated at EU level or by the different member countries by themselves (Table 3). Almost all participants indicated the EU whereas a small number chose the member countries answer (specifically a joint work between EFSA and the Spanish Agency for Food and Safety and Nutrition or similar agency at country level).

Almost all stakeholders declared that 'yes, in addition to the LNCS safety authorization process, the scientific evidence to validate their benefits beyond their capabilities of technological properties should also be incorporated' (Table 3). Those who answered 'No' gave different reasons including that additional nutritional or health claims could hinder LNCS authorisation if the purpose of its use is technological and considering that these beneficial effects are complementary and may be useful apart from a certification of scientific evidence. In addition, stakeholders mentioned that a similar process as the one established by EFSA for nutrition and health claims of food components should be followed. Finally, according to one participant's opinion, safety evaluation must be focused on the analysis of the potential risks or impacts of LNCS on diet and/or health and therefore, providing evidence that support possible beneficial effects would be more aligned with health claims, even though the evidence derived from them is strong.

A wide variety of answers were found among the stakeholders (Table 2) about the scientific evidence available in their research field or professional activity. Those who mainly disagreed that there was enough evidence pointed to several knowledge gaps: lack of knowledge about population intakes and the long-term effects or consequences of their excessive consumption and a shortage of multidisciplinary consensus

documents. Moreover, the lack of evidence in terms of the potential effects of LNCS on the immunological system of the paediatric/adolescent population, LNCS and physical activity, LNCS effects during pregnancy, lactation and menopause, or LNCS effects on gut microbiota, among others, should be considered. Moreover, stakeholders also declared that validated nutritional intervention studies are strongly needed.

The last question was focused on stakeholders' opinion on the LNCS controversy debate that is taking place in the media and social networks. As shown in Table 2, only a small percentage of the stakeholders thought the debate was appropriate whereas the majority of those surveyed somewhat or strongly disagreed that the debate was appropriate. The main reasons for this were that there is too much available information from unreliable sources, and which may be misinterpreted by a population without sufficient knowledge.

Results of the SWOT analysis

As previously mentioned, the last part of the survey was the SWOT analysis, the results of which are summarised in Table 4.

The main strengths found by the stakeholders were, firstly, that LNCS provide the opportunity to consume more palatable foods and beverages without extra calories and added sugar intake, since these compounds allow sweetening with a very low energy supply and without increasing blood glucose. Thus, they could help to reduce calories and added sugar intake and may constitute a healthy alternative to sugary drinks and foods, making them useful for the management of several pathologies and conditions, such as peripheral insulin resistance or bodyweight control. In addition,

the authorisation and surveillance systems, their safety evaluation (carried out based on scientific data), the strong and harmonised legislation of LNCS throughout the EU as well as the labelling standards and the solid scientific evidence that support them, were also considered as important strengths.

Regarding the identified weaknesses, the inability of LNCS to achieve the same organoleptic characteristics as their sugary counterparts as well as the difficulty to achieve natural flavours were widely reported. Moreover, some also agreed that public opinion on LNCS is a weakness as it may generate rejection and mistrust among some segments of society regarding their security and may have the connotation of not being 'healthy' owing to their condition of 'chemical substances'. This situation is aggravated by the negative image that certain media (television, social networks, etc.) have created of them. On the other hand, some stakeholders considered the risk of generalisation of the belief that the use of LNCS allows the consumption of any type and amount of high dense energetic foods. The rest of the weaknesses exposed referred to the scarcity and quality of scientific studies. For instance, there are few studies about the real consumption of LNCS by general population (Barraj et al., 2020; Drewnowski & Rehm, 2014; González-Rodríguez et al., 2021; Hunt et al., 2020; Redruello-Requejo et al., 2021) as well as the effect of different types of LNCS among populations suffering from diseases, on gut microbiota as well as their long-term effects (Samaniego Vaesken et al., 2021). In addition, it is important not to generalise all scientific knowledge under the broad concept of 'sweeteners', but each LNCS should be individually evaluated. Lastly, the lack of transparency on their evaluation and the complexity of legislation were also considered as weaknesses.

The main opportunities outlined by the stakeholders were that LNCS could be useful in different diseases or conditions such as overweight, obesity, diabetes and other related pathologies. In addition, it was pointed out that they might contribute to healthy diets, with lower caloric density and without sacrificing the consumption of foods with sweet flavour. On the other hand, stakeholders suggested the possibility of disseminating scientific-based information and implementing nutritional strategies to improve the overall quality of the diet as a way of counteracting the biased information conveyed by the media. Some stakeholders also highlighted the growing concern of the population for added sugars intake and bodyweight control, as well as the interest in knowing what type of products they purchase and what ingredients or additives they include. Likewise, other stakeholders found in LNCS an opportunity to develop new research, specifically focused on the study of the potential relationship between their consumption and the management of most prevalent current pathologies or on demonstrating their safety

and efficacy in risk groups. In addition, the research and positioning of other LNCS with better possibilities of safety and organoleptic application should be also contemplated. The possibility of reducing sugar content in food and drink products and reformulating and developing new products for general population and for patients with special needs, was also considered as an important opportunity according to some stakeholder. Lastly, the inclusion of LNCS in Dietary Guidelines and the improvement of nutritional labels in order to make them easier to understand by overall population were also considered as important opportunities.

Finally, the threats found by the stakeholders were the lack of knowledge, not only among general population but also from some health professionals, who often have a distorted understanding of LNCS. This fact is exacerbated by the biased information from unsubstantiated news conveyed by social networks to consumers, as well as the debate in the media and the misinformation of certain groups which have great visibility in society. Likewise, the current concern about sugary foods should not be forgotten, as well as the fact that they are not essential in diet, which could lead to consumer's rejection. Another threat identified by the stakeholders was the interest of other sectors against sweeteners such as sugar producing companies. The lack of scientific studies about their safety and adverse effects related to certain diseases and/or risk factors as well as the unavailability of a processed food composition database that include the amount of all ingredients and additives (including LNCS), were also considered as important threats. Finally, the consumption of excessive doses of LNCS and the habituation to increasingly high thresholds of sweeteners, were also a reason of concern for the stakeholders.

DISCUSSION

The increasing use of LNCS by the food industry and the growing concern of the population about health and nutrition issues, coupled with the large amount of information available to customers, make it particularly important to compile all relevant information to clarify contradictory aspects and to identify gaps in knowledge that could be filled in the near future. Therefore, the aim of our study was to collect, for the first time, the opinion, knowledge and perception of a group of key Spanish stakeholders about LNCS, their role on diet, health, safety, legal issues and food policy.

One of the main aspects highlighted by most stakeholders was that LNCS safety is warranted. In this regard, several published reviews provide evidence on the safety of these additives (Lohner et al., 2017; Toews et al., 2019) and this evidence is also confirmed by authorities including EFSA (EFSA, 2019) or the US Dietary Guidelines Advisory Committee

(McGuire, 2016). Likewise, in the last few years, several studies have been undertaken to investigate the potential short-term effects of LNCS, for example on mood, food choices or blood pressure as well as their long-term effects on different pathologies including diabetes, cancer or dental caries (Gallagher et al., 2021; Souza Bda et al., 2016; Toews et al., 2019). In addition, several recent randomised controlled trials demonstrated that the use of LNCS as a sugar replacement might help in achieving long-term reduction in excess bodyweight (Miller & Perez, 2014; Rogers et al., 2016). Furthermore, it has been also demonstrated that LNCS could improve glycaemia control when used as a replacement for caloric sweeteners. In fact, in 2011, the EFSA Panel concluded that there is sufficient information to support claims that LNCS lead to lower rise in blood sugar levels after meals, if consumed instead of sugar, and that they maintain tooth mineralisation by decreasing tooth demineralisation, when used as sugar substitutes (Sambra et al., 2020). In several studies, it has been also observed that certain healthy behaviours (referring to smoking and physical activity practice) as well as a healthier dietary profile is more frequent in LNCS consumers compared to non-consumers (Gibson et al., 2014, 2016). In any case, regarding any health benefits associated with the consumption of LNCS, it has to be taken into account that public health recommendations are to limit or avoid the consumption of foods and beverages with high sugar content (European Commission, 2001; Moxham, 2001) and LNCS constitute a feasible tool for helping to reduce sugars and overall energy intake.

However, there are still a few gaps of knowledge (Lohner et al., 2017) regarding the effects of LNCS on health or on the diet. In fact, several stakeholders mentioned the lack of studies about the ADI. In this context, it is important to clarify that the ADI is defined as 'an estimate of the amount of a food additive, expressed per kg of bodyweight that can be ingested daily by individuals over a lifetime without appreciable risk to health' (Ashwell et al., 2020; EFSA, 2019). Therefore, this parameter does not represent a maximum allowable daily intake level since it has a built-in safety margin and is based on a chronic lifetime exposure (Gibson et al., 2014). Owing to the wide margin of safety used to establish the ADI, the consumption of LNCS must exceed this value by a considerable amount and over an extended period to cause any potential harm to human health. However, if it is estimated that the population may regularly exceed the ADI, the regulatory authority may advise a reduction of LNCS levels in foods or reduce the range of foods in which their use is permitted (Ashwell et al., 2020). A recently published study carried out in a Brazilian population confirmed that the intake of six LNCS from processed foods and beverages, as well as from table-top sweeteners did not exceed their respective ADI (Barraj et al., 2020).

It is surprising that approximately half of stakeholders identified the 19 LNCS approved in the EU, despite their difficulty in remembering them individually. This fact highlights the strong need to carry out strategies to increase this knowledge, not only among customers but also within professionals. In this regard, a recent investigation in a Mexican population also revealed the unawareness of health professionals about this topic (Aldrete-Velasco et al., 2020). However, surprisingly, when participants were asked about strategies to increase the degree of knowledge about LNCS, the majority of the proposed measures were targeted to the general population and only two of the proposed strategies were focused on professionals (i.e. creating an official list with LNCS approved and a reliable database accessible to all health professionals, or conducting training sessions for professionals supported by materials and infographics). In addition, it is important to underline that almost a quarter of stakeholders surveyed, somewhat or strongly disagreed with the current labelling regulation of foods and beverages containing LNCS, since they considered that it is insufficient and not comprehensible for the consumer. According to EU labelling regulation (Martínez et al., 2020), the presence of LNCS in food or beverages must be labelled twice on food products: the name of the LNCS or the E-number must be included in the list of ingredients and the term 'with sweetener (s)' must also be clearly stated together with the name of the food or beverage product. However, the general population may not always recognise or understand this information. Therefore, the implementation of strategies that may help improving the reading and understanding of labels is of great interest.

One of the most relevant aspects of LNCS is their potential beneficial effect in the diet as well as on the prevention of several diseases or conditions. According to the obtained results, only 60% of the stakeholders thought that LNCS could help in improving diet quality. However, 76% of the stakeholders believed that LNCS could help in the management of bodyweight and 80% considered that the consumption of LNCS could contribute to reduce risk factors of certain pathologies such as diabetes or other chronic diseases. These results are in line with those recently published by the expert consensus on LNCS (Ashwell et al., 2020). Nevertheless, several stakeholders indicated their disagreement with these statements, arguing that there is not enough sound scientific evidence to support them and that diet quality as well as weight management depend on several factors, not only on one ingredient. This agrees with the perception of some nutrition experts who consider that the consumption of sweeteners should be avoided, since consumers should reduce their high preference for sweet taste (Harricharan et al., 2015). In this context, is important to cite the expert consensus recently published (Ashwell et al., 2020; Gibson et al., 2014;

Serra-Majem et al., 2018) which concluded that, when used as substitutes for sugars to reduce energy density of foods and drinks, LNCS may reduce net energy intake and assist weight management. Likewise, the expert consensus concludes that their use in diabetes control programmes, replacing sucrose or simple sugars, may contribute to a better glycaemia control. Still, they also conclude that more emphasis is required on the role of LNCS in helping individuals to reduce their sugar and energy intake (Ashwell et al., 2020).

Concerning the LNCS authorisation procedure, most respondents acknowledged that it is adequate, while only a minority considered that there are not enough analytic data on the use of LNCS, which prevents the establishment of recommended intakes or reaching conclusions on their long-term effects. In this regard, it should be pointed out that in Europe the safety of LNCS is evaluated by National Authorities, by the European Commission Scientific Committee on Food (SCF) and by the JECFA. From 1974 to 2003, the SCF was responsible for this evaluation. Since then, it became the responsibility of EFSA. Within EFSA, the Panel on Food Additives and Nutrients Sources added to Food is currently in charge of the legal regulation of these substances (García-Almeida et al., 2013; Mortensen, 2006). In the United States, since 1958 the FDA has been responsible for the safety evaluation of LNCS (Mortensen, 2006). Currently, the LNCS safety authorisation process is only focused on the security of these additives; however, most of the stakeholders believed that scientific evidence to validate their benefits should be also incorporated. In any case, it should be recognised that LNCS are among the most widely evaluated substances in the human food chain and their safety has been demonstrated by a substantial body of evidence as well as continued reviews by health regulatory agencies worldwide (Serra-Majem et al., 2018).

Interestingly, it is important to highlight that, according to the obtained results, there is an urgent and strong need for more high-quality research since, to date, there is little scientific evidence about LNCS in certain professional fields. This statement is also in agreement with expert consensus and surveys conducted to date (Aldrete-Velasco et al., 2020; Ashwell et al., 2020; Gibson et al., 2014; Serra-Majem et al., 2018). It would be very important to carry out communication strategies for professionals, consumers, research funding and the food and beverage industry. Finally, it should be noted that most of the stakeholders disagreed with the ongoing controversy on LNCS on the different media and social networks. This is undoubtedly of utmost importance since it largely determines public opinion on this type of additives. Thus, stakeholders agreed that much of the information conveyed lacks scientific evidence and/or is misinterpreted. To date, a few studies have explored customer's perception and understanding on messages they receive from authorities or industrial

associations (Bogart et al., 2019). Therefore, the monitoring of consumer perception and understanding of messages may be of potential interest in the future, in order to clarify, not only the understanding of the disseminated information by general population but also their effect on food choices and dietary habits.

In conclusion, there is a range of opinion of the stakeholders surveyed regarding several of the topics, especially the possible role of LNCS in dietary quality and the scientific evidence available according to their professional field. Effective communication strategies to inform professionals and the general population, as well as new research that deepens the knowledge of LNCS are urgently needed.

AUTHOR CONTRIBUTIONS

Conceptualisation, G.V.-M. and T.P.; methodology, G.V.-M.; T.P., A.I.L.G. formal analysis, T.P. and A.I.L.G.; investigation, T.P., A.I.L.G., M.d.L.S.-V. and A.M.P.; resources, G.V.-M. and T.P.; data curation, A.I.L.G.; writing – original draft preparation, A.I.L.G.; writing – review and editing, G.V.-M., T.P., M.d.L.S.-V., A.I.L.G. and A.M.P.; visualisation, A.I.L.G.; supervision, T.P. and G.V.M.

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CONFLICT OF INTEREST

The authors confirm that they have no conflicts to report.


DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.


ETHICAL APPROVAL


The study was conducted according to the guidelines of the Declaration of Helsinki. and approved by the Clinical Research Ethics Committee of the CEU San Pablo University, with code 447/20/27.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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