

RUNNING HEAD: COTTON CANDY: A GASTROPHYSICAL INVESTIGATION

Cotton candy:

A gastrophysical investigation

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ABSTRACT

The first mechanical device for making cotton candy, sometimes referred to as candy floss in the UK and New Zealand, and fairy floss in Australia, was patented in North America in the closing years of the 19th century. Ever since, this popular technique for transforming a simple base ingredient into a much more voluminous spun sugar confection (often with the addition of food colouring and flavouring) has been a popular staple treat for children in many parts of the world at fairgrounds, funfairs, and the seaside. Intriguingly, however, this (in a sense) early molecular gastronomy, or modernist cooking technique (involving, as it does, the radical transformation of an ingredient) has, until recently, remained firmly in the category of ‘entertainment’ food. As such, the particular texture / appearance of this confection tends to be uniquely connected in many people’s minds to childhood pleasure hence perhaps also triggering nostalgic thoughts. In recent decades, a number of famous chefs, such as Ferran Adrià and José Andres, have started to incorporate cotton candy into some of their sweet (and, on occasion, savoury) culinary creations. Here, we describe a novel amuse bouche, called ‘A study in white’, in which four differently-shaped/textured colourless white edible bites were served to diners in a restaurant setting. In this case, the latter were encouraged to try and determine which of the four so-called basic tastes (sweet, sour, bitter, or salty) they would associate with each texture/shape in the absence of any other sensory cue. Perhaps unsurprisingly, the chef chose cotton candy as the most unambiguous textural cue to connote sweetness, a cue that many of the diners immediately picked-up on. A follow-up online cross-cultural study revealed that both Spanish- and English-speaking participants (N = 339) associated candy floss more strongly with sweetness than even something that looked like a sugar cube.

KEYWORDS: COTTON CANDY; CANDY FLOSS; SPUN SUGAR; MOLECULAR GASTRONOMY; TRANSFORMATIVE TECHNOLOGY

Introduction

Cotton candy, otherwise known as candy floss or fairy floss, is a uniquely-textured sugary treat that most people nowadays typically associate with the fair. While originally the preserve of European royalty, this positively-valenced food was brought to the masses following the development of the mechanical cotton candy machine around the turn of the 19th century. Over the course of the last century or so, it has become a ubiquitous sugary children's confection. As such, cotton candy is likely to trigger nostalgic thoughts of happy childhood memories (e.g., see Rupp, 2016; Swarns, 2014). Intriguingly, however, a growing number of haute cuisine chefs have recently started to incorporate it into the sweet and, on occasion, savoury dishes they serve. Along the way, a range of unusual new flavours have been trialled, potentially leading to a negatively-valenced disconfirmation of expectation response amongst diners (who might well be expecting a childhood sweet vanilla or raspberry flavour) unless their first exposure is carefully managed.

In this review, we take a gastrophysics perspective on the subject of cotton candy (see Spence, 2017b), meaning that our focus is not merely on the ingredients/preparation of this intriguing foodstuff. Rather, we are just as interested in the associations that this most celebratory and unusually-textured food has in the minds of those who consume it. After all, knowing what is going on in the minds of the diners is likely to prove key to delivering the most successful dishes in the setting of haute cuisine. Finally, we introduce a new amuse bouche, 'A study in white' that plays on people's associations with this unique texture. We also present the results of an online study conducted on 339 Spanish- and English-speaking participants showing that people experience a strong association between the form/appearance of candy floss and sweetness, an association that is stronger even than the association they experience between something that looks like a sugar cube and sweetness. The other elements of the study in white dish were not, however, so clearly associated with their anticipated basic tastes. Reasons for this surprising pattern of results are discussed.

On the early history of spun sugar

Sugar is both a sought after food by humans as well as being a highly-versatile culinary ingredient (Macinnes, 2002). Throughout human history, chefs have been known to manipulate sugar in various ways in order to create all manner of (in some cases semi-) edible delights, pleasing both to the stomach and the eye. Probably the most well-known example of this is the

19th Century French celebrity chef Marie-Antoine Carême (Carême, 1828). His decorative confectionery centre pieces, also known as *pièce montée*, were designed in an architectural or sculptural form (Goldstein, 2015, p. 113). Carême was famed for his spun-sugar windmills, fountains, gondolas, temples, and palaces (see Horwitz & Singley, 2004).

According to Richardson's (2003), *Sweets: A History of Candy*, spun sugar first appeared in the 15th Century, with Italian cooks starting to fashion exotic and fine sculptures from spun sugar (see also Tannahill, 1973, p. 187). The cooks would first melt sugar in a pan, before pulling it out with a fork and finally, collecting the thin strands over a wooden broom handle. Meanwhile, according to the historical records, on a state visit to Venice in the 16th Century, Henri III of France, was treated to an all-sugar banquet, complete with spun-sugar cutlery and tablecloth (Rupp, 2016). However, by the 18th Century, even the less exalted household cook was being encouraged to try her hand at making spun sugar. Elizabeth Raffald's (1769) *The Experienced English Housekeeper* (as cited in Colquhoun, 2003), for instance, includes recipes for gold and silver webs for covering sweetmeats. These were made by drawing sugar syrup up with a knife tip and whipping it "*as quick as possible backwards and forwards*" across a mold made from an inverted buttered bowl (see Goldstein, 2015; Rupp, 2016). It is important to note here that spun sugar, though in some ways similar to cotton candy, would not have the latter's same fine cottony texture.

Cotton candy as fairground food

A mechanical device for the making of cotton candy was first patented in The United States back in 1897 (see Rupp, 2016).¹ According to McGee (2008, p. 688), it was introduced to the general public during the 1904 Louisiana Purchase Exposition, popularly known as the St. Louis World's Fair. This mammoth event attracted somewhere in the region of 20 million visitors over a 7-month period. During that time, Morrison and Wharton sold nearly 70,000 helpings of cotton candy at a price of 25¢ a box – the equivalent of something like \$7 today (Rupp, 2016). It was sold in wooden boxes as "fairy floss". In 1921, another dentist, by the name of Josef Lascaux coined the term 'cotton candy' which soon came to replace 'fairy floss' as the descriptor for this sugary treat. Meanwhile, Morrison and Wharton's somewhat temperamental apparatus was eventually improved upon by Cincinnati-based Gold Medal

¹ Ironically, given sugar's effect on teeth, the original patent for an electric candy machine was filed by a dentist, William Morrison working together with the confectioner John C. Wharton (Goldstein, 2015; Rupp, 2016).

Products in 1949, with the addition of a spring-loaded base. To this day, the latter company is still the major producer of cotton candy machines (Rupp, 2016). This sugary confection has been a stalwart of the fairground / theme park food scene ever since. For instance, Bailey (n.d.) mentions candy floss machines being used in the fairgrounds in the 1940s in the UK.

The mechanical device for making cotton candy can reasonably be described as a transformative food technology; one that is both playful and, as it so happens, an increasingly trendy part of the offering in the upper echelons of haute cuisine, especially in what one might term ‘Adrià-inspired’ restaurants (i.e., those that practice what Spence and Youssef, 2018, refer to as ‘experimental cooking’).

The process of making candy floss involves spinning sugar in a heating bowl at 149°C. The rotating bowl, spinning at roughly 3,450 revolutions per minute, spews out filaments of molten sugar measuring no more than 50 microns in diameter (Rupp, 2016). The latter instantaneously solidify, with the sugar syrup cooling so quickly it does not have the time to re-crystallize. Cotton candy is, in fact, the sugar version of glass (see Barham, Skibsted, Bredie, Bom Frøst, Møller, Risbo, Snitkjær, & Mortensen, 2010). The sugar can be dyed in different colours and infused with various flavours. The most popular colour-flavour combinations being vanilla-flavoured pink and raspberry-flavoured blue cotton candy, according to Swarns (2014). The latter combination is particularly interesting given the common suggestion that consumers are averse to blue foods (see Spence, 2018, for a review). Intriguingly, the blue raspberry combination found in cotton candy apparently predates the rise in popularity of this particular combination of colour and flavour popular in soft/iced drinks.

Nostalgia on the menu

Cotton candy is an unusual food inasmuch as, until very recently, it had no place in haute cuisine (see Wagstaff, 2015). In fact, it was a food (or rather a food texture) that was mostly found only at the fun fair / fairground (Brocklehurst, 2014; Stevenson, 2008). As such, many people tend to be reminded of happy childhood holidays when they think of this sugary treat (Rupp, 2016; Swarns, 2014).² One might even want to position cotton candy/candy floss as a positively-valenced comfort food (see Spence, 2017a, for a review). Indeed, it is interesting to

² Cotton candy is not, of course, unique in this regard. In fact, the fairground/funfair was also full of other sugary snacks, from brandy snap through toffee (or taffy) apples (Mason & Brown, 2006, p. 178), possibly rock, and, once upon a time at least, boiled sweets and jujus (Rupp, 2016).

note that in Darra Goldstein's (2015, pp. 190-191) superlative volume *The Oxford companion to sugar and sweets*, the entry on cotton candy is illustrated by a picture of a couple of young children indulgently enjoying themselves eating the stuff.

The texture of cotton candy is not something that really has any other associations except perhaps for those familiar with its occasional use at the hands of the modernist chefs (see below). As such, serving cotton candy in the context of a restaurant is likely to trigger positive and nostalgic feelings. It is, in fact, rare to find a food that has such strong positive associations across cultures and one that is so closely associated with childhood. Given that many of the world's leading chefs show an interest in engaging their guests emotionally, and that nostalgia (especially in terms of smell and flavour) is such a common theme, one that is used to try and engage diners (e.g., see Leonor, Lake, & Guerra, 2018), it seems only right to re-evaluate this very simple yet visually impressive food. Just take, for instance, the following quote on the theme of nostalgia: "*The key ingredient infused into every Alinea meal isn't a mountain of caviar, or a fat puck of foie gras. Since Alinea's debut in 2005, chef and owner Grant Achatz has built a reputation for designing dishes spiked with emotion; eliciting playful nostalgia from his diners via sophisticated riffs off a peanut butter and jelly sandwich, or pheasant served with smouldering oak leaves – aromas of fall.*" (see <https://www.theworlds50best.com/The-List-2018/31-40/Alinea.html>). One finds a similar sentiment at Mugaritz, in San Sebastian, where chef Andoni Aduriz aims to serve not only food, but also to play mind games. In fact, he has been quoted as saying "*I want to tantalize not just the palate, but the mind. I tell my waiters: 'our work is not to sell food, but feelings'.*" (Robinson & Piggot, 2012).

Cotton candy in haute cuisine/ experimental cooking

Ever since its introduction, this popular technique for transforming a simple base ingredient, sugar, into a much more voluminous spun sugar confection (often with the addition of food colouring and flavouring; see Swarns, 2004) has been a popular children's treat (traditionally served on a stick, and latterly simply in a plastic bag) at fairgrounds, funfairs, and at the seaside (e.g., Brocklehurst, 2014; Stevenson, 2008). Indeed, if it weren't made essentially from just pure sugar, one could see how the phenomenal increase in volume that occurs when sugar is transformed into cotton candy, would fit with contemporary trends toward aerating foods in

order to try and ‘trick’ the diner/consumer into believing that there is more food than is actually the case (Arbolea, García-Quiroga, Lasa, Oliva, & Luis-Aduriz, 2014).³

The cotton candy machine can, we would argue, be considered a molecular gastronomy / modernist piece of equipment. In a sense, the machinery required to make cotton candy, facilitating as it does the transformation of the texture of an ingredient can be considered an early food transformation that fits right in with the molecular gastronomy / modernist cuisine movement (see Wagstaff, 2015; Youssef, 2013; though see also Spence & Youssef, 2018). At the same time, however, the method of making cotton candy (and the science behind it) doesn’t even merit a mention in Myhrvold and Young’s (2011), *Modernist cuisine*; Nor, for that matter, does it appear in either Alan Davidson’s (1999), *The Oxford companion to food*, nor in Colin Spencer’s (2003) thousand years of British food history. Harold McGee (2008, p. 688) does little better, giving cotton candy no more than the briefest paragraph in his compendious volume *On food and cooking*. And yet, the transformation of ingredients from one state to another (in many cases less identifiable) state is a common characteristic of modernist cooking. For instance: “Chef Ferran Adria defines his cooking as “deconstructivist”. He defines the term as “taking a dish that is well known and transforming all its ingredients, or part of them, then modifying the dish’s texture, form and/or its temperature. Deconstructed, such a dish will preserve its essence, but its appearance will be radically different from the original.” (<https://greatchefs.com/chef/ferran-adria/>).⁴

Indeed, another link between the cotton candy machine and modernist/molecular gastronomy is precisely this focus on texture. As hinted at in the above quote, part of Ferran Adrià’s motivation for transforming ingredients was to look at introducing ‘new’/unique food textures into the dining experiences. One other point that is perhaps worth stressing here is that the process of making cotton candy is purely for textural transformation, unlike smoking, curing, salting, roasting etc. That is, turning sugar into cotton candy serves no ‘useful’ purpose. That said, while cotton candy is fun and delicious, we are unlikely to eat sugar in its unprocessed form. Not many people, after all, would choose to eat a spoonful of sugar for fun. So, it is not

³ Despite being made essentially from nothing by sugar, a head-sized portion of cotton candy still contains fewer calories than a can of regular can of cola (Rupp, 2016).

⁴ That being said: “In the past, critics have commented that *elbulli* does not value the quality and purity of natural ingredients, that products undergo too many process and are transformed into different textures and preparations in a way that ignores or overlooks their intrinsic qualities.” (Lopez, 2011).

really the ingredient that is key to liking, but rather the way in which that ingredient is processed that is key here.

Part of the unique textural attraction of cotton candy is how the agglomerated strands of sugar melt just as soon as they come into contact with the mouth. This ‘disappearing’ act is yet another feature found in numerous other ‘molecular gastronomy/modernist’ techniques including ‘airs, a technique popularised by elbulli in dishes such as Carrot air with mandarin granita (see Lubow, 2003; McIntyre, 2012). A culinary ‘air’ is a flavoured emulsion of liquid and gas (with lecithin often used as an emulsifier/stabilizer). The structure, a moderately stiff network of bubbles/foam, again tends to dissipate once it makes contact with the mouth (see **Figure 1**). Other ‘disappearing foods’ include the ‘obulato’ sheets, the wafer thin, transparent, edible films, made of rice and potato starch. These sheets are commonly used by modernist chefs to create small canapes or garnishes. The obulato sheets are typically brushed with a syrup and dehydrated to form a crisp, or filled with an oil based substance (as liquids with a high water content will dissolve the film). The film all but disappears in the mouth save for a slight starchy residue. And then, of course, we have the nitro poached aperitif served at Heston Blumenthal’s *The Fat Duck* in Bray that again disappears in the mouth leaving nothing more than a puff of smoke (Blumenthal, 2008).

INSERT FIGURE 1 ABOUT HERE

Intriguingly, however, over the last two decades or so, spun sugar (i.e., cotton candy) started to appear more frequently in El Bulli (closed 2011; see Edwards, 2011), and other haute cuisine establishments. Indeed, it has made an appearance in a number of famous restaurants, often at the hands of chefs (Wagstaff, 2015), who had previously passed through el Bulli kitchens, at some point in their careers (see **Figure 2**). For instance, chef José Andrés serves a cotton candy foie gras combination at his restaurant The Bazaar in Los Angeles. Even the mojito comes with a cotton candy garnish in this popular restaurant. Meanwhile, maple syrup flavoured cotton candy is served with brown sugar angel food cake at Boston restaurant Towne Stove and Spirits. However, while the use of cotton candy in modernist cuisine might seem a very recent trend, it is perhaps worth noting that New York’s *Four Seasons Restaurant* has been serving it to those in the know (i.e., it doesn’t appear on the menu) since the 1970s (all examples from Wagstaff, 2015).

INSERT FIGURE 2 ABOUT HERE

While pink vanilla and blue raspberry may well be the most popular flavours for cotton candy at the fair, modernist chefs are increasingly incorporating a range of novel flavours into the mix, such as mocha mint, mango chili, watermelon, salted caramel, and lychee green tea (Rupp, 2016; Wagstaff, 2015). Given that such flavours are likely unexpected in this format, there is undoubtedly a danger of disconfirmed expectation (Yeomans, Chambers, Blumenthal, & Blake, 2008) unless managed carefully, e.g., by careful dish naming/description; see Spence, 2017b, Spence, Navarra, & Youssef, 2019, on this theme). And while surprise/novelty is valued, and in some cases even expected, in molecular/modernist restaurants (see Spence, 2017b; Velasco et al., 2016), unless carefully managed (and/or occurring in the right context) it is likely to result in a reduced liking (i.e., lowered valence) for the taste (or rather flavour) of the food itself rather than with the unexpectedness of the situation (see Piqueras-Fiszman & Spence, 2015; Schifferstein, 2001).

A 'Study in white': Amuse bouche

The 'Study in white' amuse bouche was served to diners at a series of Kitchen Theory – Gastrophysics dining experiences held at the Andaz Hotel in London in the summer of 2016. This dish can be seen a straightforward riff on '*The four tastes*' served at chef Jozef Youssef's chef's table (see Velasco, Michel, Youssef, Gamez, Cheok, & Spence, 2016). In the latter dish, diners were presented with a random arrangement of four clear spoons, each containing a spherified colourful flavoured liquid. The diners were encouraged to arrange their spoons from left to right on the table in the order: salty, bitter, sour, and sweet. The diners' responses, which were presumably based on their colour-taste associations (see Saluja & Stevenson, 2018), were then used as data for experimental research on colour-flavour correspondences (e.g., see Spence, Wan, Woods, Velasco, Deng, Youssef, & Deroy, 2015). Notice how, in this case, the spherification effectively removed any olfactory cues to cue the guests as to which colour was matched to which taste/flavoured solution, meaning that colour was pretty much the only cue that the diners had to go on when making their choices about the colour of taste.

INSERT FIGURE 3 ABOUT HERE

In the 'Study in white' dish (see **Figure 3**), we wanted to do something very similar, but this time on the theme of shape/texture–taste crossmodal correspondences instead. The dish was designed to look at how the absence of colour made the decision concerning the 'correct order' more difficult and therefore guests had to rely on other cues when making their judgment. This

also got them more mindful of the details of each dish that might otherwise simply just be taken for granted. This dish also builds on the recent growth of research interest in such crossmodal correspondences amongst scientists (e.g., see Spence & Deroy, 2012, 2013; Turoman, Velasco, Chen, Huang, & Spence, 2018). According to one account, the spatiotemporal transitions that are associated with our experience of each of the basic tastes might be mapped onto shape properties (see Obrist, Comber, Subramanian, Piqueras-Fiszman, Velasco, & Spence, 2014). Alternatively, however, according to another suggestion, we may simply match liked shapes with liked tastes and put disliked tastes/shapes together. Of course, on occasion, shapes/textures might also be mapped onto tastes as much because of the distinctive foods that we associate with a particular shape/texture (cf. Saluja & Stevenson, 2018). In this regard, it is obviously hard to think of any texture/food that is more iconically sweet than cotton candy.⁵

INSERT FIGURE 4 ABOUT HERE

For ‘A study in white’, guests were served four ‘bites’ each a different shape and texture, but all predominantly white (see **Figure 4**, for a close-up highlighting the detail of each of the elements). They were told that each of the four bites corresponded to one of the four basic tastes. They were instructed by the server to eat the dish in a particular sequence (salty, bitter, sour, sweet), relying on visual cues (other than colour) such as shape and texture in order to make their judgment as to the correct order in which to consume the elements. Interestingly, many guests mentioned that they instantly knew that the candy floss texture had to be sweet, and from there, they went on to try and figure out the rest of the elements. The angular asymmetric shape for the sour-tasting element was again based on the latest laboratory research (e.g., see Turoman et al., 2018).

When served at the Andaz Hotel, the salty-tasting element was deliberately misleading, as its shape (round) and texture (soft) are more commonly associated with sweetness, yet with the cotton candy being a much more obvious candidate for the sweet element of the dish, guests were forced to rely on a process of elimination. Finally the bitter element was the most ambiguous of all the shapes, yet the rough ‘Styrofoam’-like texture was intended to allude to the bitterness. In this sense, two of the elements (the sour and sweet) were reasonably obvious whereas the other two elements (salty and bitter) were much more ambiguous. This encouraged discussion between the diners and differing opinions and thoughts regarding shape, texture,

⁵ Note that here it is often unclear whether white crystals are sugar or salt, and hence this format is intrinsically ambiguous.

and taste/flavour correlations to dominate the conversation at the dining table throughout the course. Another example of mindful dining.

Recipe/Preparation/Ingredients

Cotton Candy		10 servings
Ingredients	Quantity	Measure
Sugar	60	g

Cotton candy (sweet)

1. Warm up the cotton candy machine
2. Add the sugar.
3. Collect the cotton candy with a wooden stick.
4. Serve immediately.

<i>Ajo Blanco Square</i>		10 servings
Ingredients	Quantity	Measure
Almonds	25	g
Almond milk	95	g
Agar Agar	1	%
White Bread, no Crust	7.5	g
Garlic	0.75	g
Extra Virgin Olive Oil	4	g
Sherry Vinegar	1.7	g
Salt	1.3	g

Ajo blanco square (salty)

1. Using a hand blender mix all the ingredients together aside from the agar agar.
2. Heat up a third of the mixture to 80°C and add the agar agar.
3. Mix well, and allow to cook for 2 minutes.

306 4. Put in square molds (3cmx3cm), and place in the fridge for 1h.

307 5. Unmold and serve.

308

Obulato and Cod		10 servings
Ingredients	Quantity	Measure
Obulato (7x7cm)	30	pieces
Cod	50	g
Lime Juice	10	g
Salt	1	g
Olive Oil	10	g
Egg White	30	g

309

310 Obulato and cod (sour)

311 1. Using a small pastry brush; brush a sheet of obulato with egg white.

312 2. Add another obulato sheet directly on top and brush with egg white. Repeat one more time.

313 So there are 3 sheets layered on top of each other in total.

314 3. Put the obulato in the dehydrator at 55°C, for 12hrs or until crisp.

315 4. Cut the cod in small pieces (approx. 0.5cm), add the lime juice and salt, and marinate for

316 15 minutes.

317 6. Strain the fish, and add olive oil.

318 7. Serve the cod on top of an obulato crisp.

319

Metil Meringue and Beetroot		10 servings
Ingredients	Quantity	Measure
Metil	1.66	g
Water	166	g
Castor Sugar	16.66	g
Xanthan Gum	3.66	g
Beetroot	200	g
Coco Powder	15	%

320

321 Meringue and beetroot (bitter)

1. Using a hand blender mix the water sugar and metil.
2. Add the xantan gum powder and continue to mix.
3. Place the mix into kitchen stand mixer and whip using a baloon whisk attachment, until it looks like a meringue.
4. Portion and shape into an oval.
5. Put the meringue into a dehydrator at 50°C until crisp (usually 24hrs).
6. Peel and cut the beetroot in to approximately 2cm cubes and *sous vide* at 90°C for 3 hours.
7. Blend in a mixer.
8. Transfer to a pan over a medium heat, reduce to half of its volume.
9. Add the cocoa powder, and cool.
10. To serve, pipe the beetroot coco puree into the meringue.

Online study to assess shape/texture associations

The consensuality of the mapping of the basic tastes onto the four visual food elements was assessed in an online study with a convenience sample of Spanish- and English-speaking participants (N = 287 and 52, respectively). The participants were sequentially shown the four items individually and asked to decide which of the basic tastes they associated with each element. The participants were given four choices (bitter, sweet, sour, and salty in the English-language version and dulce, salado, ácido/agrio, and amargo in the Spanish version). The participants were also asked how confident they were about their response (on a scale from 1- Not at all confident to 5 – Very confident). Finally, at the end of the study, the participants were invited to describe the basis on which they had made their choices (cf. Saluja & Stevenson, 2018).

INSERT TABLE 1 ABOUT HERE

The results (see **Table 1**) revealed that the majority of participants (both Spanish-speaking and English-speaking) associated sweet (dulce) with the candy floss element, as expected. Intriguingly, if anything, the candyfloss was actually even more strongly associated with sweetness than the element that had been designed to look like a sugar cube in our online test.

However, contrary to our expectations based on the prior shape-taste correspondence research using outline shapes (see Turoman et al., 2018), the asymmetric pointy-shaped element was not preferentially associated with sourness. That said, this was the element (out of the four shown to participants) that was least strongly associated with sweetness. The fourth shape again showed a modest association with sweetness in both samples, perhaps triggering an association with the appearance/texture of merengue, which itself tends to be sweet. In the majority of cases, participants primarily responded with a 3 or 4 when asked how confident they were of the association they chose.

As to why the angular asymmetric shape, that was chosen, based on the research (Turoman et al., 2018) to suggest sourness, was not so interpreted by the participants in our online study remains uncertain. Here, though it is worth highlighting the fact that previous research on shape-taste correspondences has largely focused on outline shapes that have no obvious relation to food stimuli (see Cytowic & Wood, 1982; Deroy & Valentin, 2011; though see also Fairhurst, Pritchard, Ospina, & Deroy, 2015; Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012).⁶ By contrast, the results of the present study, together with the justifications provided by a number of the participants after they had made their choices suggests that basic tastes were often chosen for the visual elements on the basis of prior food experiences (cf. Saluja & Stevenson, 2018, for a similar account of how many participants go about matching tastes to colours), rather than on the basis of any associations with the outline shape properties (e.g., “Familiar from food types I know”; “Relate to previous experience of eating things that shape i.e. Candy floss, sugar cube, etc”; “Similar shape to familiar foods”; “Previous experiences”; “They remind me food with the specific taste I've chosen”; “They are designed to remind me of known foods: candyfloss, sugar cube, sugar-work, cream - all things which I identify as such given my cultural and social background. It's not the shape as such, it's what the object reminds me of, plus the white colour being easily associated with the substances of sugar and cream. Are other people seeing these shapes in different colours?!”; “Past childhood and dining experiences”).

In this regard, it is interesting to note how chef Jozef Youssef's spherification in the four tastes amuse bouche (see Velasco et al., 2016) ended-up providing spheres of colour that were

⁶ Here it is interesting to note that Sir Robert Boyle (1627-1691) the famous British natural philosopher, chemist, physicist, and inventor also associated shapes with tastes (Alexander, 1985).

unlikely to trigger any specific food associations (attributable to the form of delivery) in those who tasted the dish/took part in the study.

Taken together, these results clearly demonstrate the robust association between sweetness and candy floss, thus confirming the suggestion developed earlier in this article. The item that looked like a sugar cube was, unsurprisingly, also associated with sweetness. However, the results for the other two elements was less clear-cut. As such, these latter results stand in marked contrast to the robust associations that were established between the four colours and the four tastes in our previous research (see Spence et al., 2015; Velasco et al., 2016). Here, though, the explanation for this difference may come from the participants' reports concerning why they chose the tastes they did for the shapes/textures. In particular, as has been reported recently with the colour-taste associations (e.g., as assessed by Saluja and Stevenson, 2018), many people said that they associated tastes with shapes (and colours) on the basis of their memory of foods that they have eaten previously. At the same time, it is also worth noting that Gil-Pérez, Rebollar, Lidón, Martín, van Trijp, & Piqueras-Fiszman (2019) have also reported how angularity may need to be complemented by other cues in order to best convey a specific taste quality (spicy heat in their case).

Nevertheless, regardless of the specifics of the results, it should be noted that the aim with this dish (amuse bouche) was as much to give rise to discussion amongst diners at the start of the meal (think of it as something of an ice-breaker). Hence, having some disagreement is desirable, and thus the dish succeeded as intended. That said, there is more work to be done in terms of identifying whether there are real food shapes/textures that are most strongly associated with sourness, bitterness, and saltiness.

Conclusions

In the Middle Ages, spun sugar was a rare delicacy to be enjoyed on special occasions by the very rich. That said, the first mainstream recipe for spun sugar dates back to 1769 (see Raffald, 1769). While the mechanization of cotton candy production (and having a much finer texture than spun sugar) was patented back in 1897, it was the 1904 World's Fair where this novel voluminous food texture first made its appearance as a popular 'entertainment' food. Thereafter, this relatively uniquely-textured food has remained primarily the preserve of the fairgrounds and fun fairs. Given that this food's texture, together with the sweetness that it unambiguously signifies, is only really associated with pleasurable childhood treats, it is

understandable why chefs interested in triggering nostalgia might be tempted to use it in the dishes that they serve. No wonder, then, that cotton candy has, in recent years started to appear in a number of dishes, both savoury and sweet, from Ferran Adrià and a number of those other chefs who have passed through the *el bulli* kitchens. However, as reviewed here, cotton candy's transformative nature, both in the act of creation, as well as its immediate disappearance on consumption also place it firmly within the modernist, or experimental cooking, repertoire (see Spence & Youssef, 2018). As to whether it makes sense to describe the invention of the candy floss machine as the first piece of molecular gastronomy (or modernist) kitchen equipment, we are happy to leave others to decide (though see Spence & Youssef, 2018, on terminological disputes in this area).

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FIGURE LEGENDS

Figure 1. Sudden transformation. Dishes that disappear in the mouth: A) Carrot air with mandarin granita (El Bulli, by Ferran Adria); B) Clear Canapé – Asparagus, Miso Foam, Malt Crumble (www.molecularrecipes.com/surprises/clear-canape-asparagus-miso-foam-malt-crumble/).

Figure 2. A selection of dishes highlighting the appearance of candy floss as a component of the dishes in a number of molecular gastronomy / modernist restaurants: A) The Cotton candy tree, as served at Tickets – Ferran/Albert Adrià (<http://www.luxeat.com/blog/tickets-ferran-adria/>); B) Course 9: "ninfa de algodón" ("Cotton nymph") - Cotton candy filled with Thai vegetables, herbs, spices (fennel at least), sprouts, nuts, and a dark brown tamarind sauce. Basically a really fresh and slightly sweet spring roll. Ferran Adrià – elbulli (<http://foo.net/~blakej/meals/elbulli/outside.html>; see also Spence & Piqueras-Fiszman, 2014); C) Flower Paper from Ferran Adrià (<http://eattravelspace.blogspot.com/2011/07/el-bulli.html>); D) Foie gras cotton candy from José Andrés (worked at elbulli) of Bazaar in the SLS Hotel in Los Angeles, CA., Andrés (<https://www.pinterest.ca/pin/243687029806941614/>; see also Wagstaff, 2015); E) Chef Jesús Escalera (worked at elbulli hotel) - pastry chef at La Postrería in Guadalajara, Mexico (<https://wineandfoodfest.com/en/personality/chef-jesus-escalera/>); F) Mocha mint cotton candy served on an actual stalk of cotton, by chef Oriol Castro (former elbulli head chef) https://www.tripadvisor.co.uk/LocationPhotoDirectLink-g187497-d7281314-i245033496-Disfrutar-Barcelona_Catalonia.html); G) Osetra Caviar: lobster, meyer lemon, cotton candy, as served by Chef Grant Achatz, Alinea (Achatz estaged at elbulli) <http://www.lthforum.com/bb/viewtopic.php?f=14&t=9414&start=270&sp=450857>); H) Atelier crenn – Mint Cotton candy as served at Atelier (<http://www.foodfashionista.com/2012/10/atelier-crenn-shines-bright-with-michelin-guide-2013-star-announcements.html>). Note that the latter chef is perhaps the only one whose work is displayed here not to have worked at ElBulli.; I) Barbapapa with mint, curry and tamarind (from Adria, Soler, & Adria, 2006).

576 Figure 3. A “Study in white”. This colourless (i.e., completely white) amuse bouche was served
577 at a series of dining events held at the Gastrophysics Chef’s Table in London in 2016
578 (<https://gastrophysics.co.uk/>). The diners were encouraged to try and figure out the likely taste
579 of each morsel (sweet, sour, bitter, and salty) based on the shape/texture and nothing else.
580 Notice how, in developing the dish, the chef (J.Y.) immediately reached for candy floss as the
581 texture to associate with sweetness. From top to bottom: Methycellulose cloud - eggless
582 meringue, with coffee cream (bitter); Spherification of Ajo Blanco (salty); Obulato with lime
583 marinated fish (sour); Cotton candy (sweet).

584

585 Figure 4. Close-up shots of each of the elements in the “Study in White” dish served to diners
586 at the Adnaz Hotel in London. A) Sweet; B) Sour; C) Bitter; and D) Salty.