RUNNING HEAD: SEASONAL PATTERNS OF FOOD CONSUMPTION

Explaining seasonal patterns of food consumption

Prof. Charles Spence,

Head of the Crossmodal Research Laboratory, University of Oxford

SUBMITTED TO: *International Journal of Gastronomy & Food Science*

WORD COUNT: 9,150 WORDS

DATE: DECEMBER, 2020

CORRESPONDENCE TO: Prof. Charles Spence, Department of Experimental Psychology, Anna Watts Building, University of Oxford, Oxford, OX2 6GG, UK. E-mail: charles.spence@psy.ox.ac.uk

ABSTRACT

When questioned, people typically report that different foods are appropriate at different times of the year. That is, patterns of food consumption exhibit seasonal variations. Changes in food odour hedonics and familiarity ratings have also been reported over the course of the year, especially in those countries with marked seasonal changes in climate. The question addressed in this review is what factors help to explain these seasonal differences in food consumption. While our nutritional needs undoubtedly do differ somewhat over the course of the year, environmental (e.g., think only of changes in ambient temperature and/or humidity), physiological/perceptual (i.e., threshold changes), and psychological factors (e.g., wanting to make a healthy start in the New Year) also play a role. Taken together, though, it would appear that cultural/ritual factors, as well as the influence of increasingly-sophisticated data-driven marketing may be more important than nutritional, environmental, or physiological factors in helping to explain why it is that so many of us choose to eat different foods at different times of the year, despite the increasing availability of many foods on a year-round basis in the increasingly globalized food marketplace in many developed countries.

KEYWORDS: SEASONAL; FLAVOUR; TASTE; OLFACTION; MOOD.

1. Introduction

Patterns of food consumption vary over a number of different timescales: There is, for example, evidence of diurnal (see Spence, 2017a; and Spence, submitted, for a recent review), weekly (e.g., Carman & Figueroa, 1986; Cohen, 2011; de Castro, 1991), and monthly (e.g., Allen, 2016; St. Jeor, Guthrie, & Jones, 1983) variations in the types (not to mention the amount) of food that many of us choose to consume (see also Cornelissen, Singh, Schwartzkopff, & Halberg, 2013, for a number of other temporal scales of variation that may affect human behaviour). Many researchers have, though, chosen to focus their efforts on trying to map out, and thereafter to study, the annual patterns in food consumption. Once-upon-a-time, of course, these would primarily have been driven by seasonal constraints on the availability food (e.g., linked to the harvest). The limited availability of different sources of food at different times of year would therefore have exerted a far more profound (exogenous) influence over our seasonal patterns of food consumption than they do today. A number of seasonal foods may still be linked to particular times of year as a result of cultural/ritual associations (e.g., Thanksgiving or Christmas).

By contrast, nowadays, those with access to the highly-developed, and increasingly globalized, food marketplace, are able to buy a wide array of different foods, including fresh produce, on a seemingly perennial basis (see Joachim, 1997a; Sobal, 1999; Spence, 2020). Hence, given the widespread availability of so many of our preferred foods on a year-round basis, it becomes interesting to ask whether there are nevertheless still any significant seasonal/annual variations in the foods and beverages that we choose to consume. And, if so, the obvious follow-up question becomes one of determining what the key factors underpinning the maintenance of these temporal patterns in our food behaviours might be.

As we will see momentarily, a growing number of studies have highlighted significant seasonal differences in the patterns of food and beverage consumption amongst humans (e.g., Joachim, 1997b; Löwik, Hulshof, Brussaard, & Kistemaker, 1999; Young, Smudski, & Steele, 1951). That being said, the nature of these temporal variations appears to depend, at least to a certain extent, on where in the world one happens to live (e.g., whether we live in a climate that is more seasonal or not). While our nutritional needs undoubtedly do differ somewhat over the course of the year, environmental (e.g., think only of changes in ambient temperature and/or humidity), perceptual (i.e., possible threshold changes), and psychological factors (think here only of the change in mood as the nights draw in, in the cold winter months, not to mention many people's desire to make a healthy fresh start at the beginning of the year, after indulging at Christmas; see Pope, Hanks, Just, & Wansink, 2014) also undoubtedly play a role too. Indeed, as we will see later, the increasingly influential role of intelligent data-driven seasonal (and weather-event related) food marketing should not be ignored here either in terms of its ability to help sustain such seasonal patterns of food consumption (see Cohen, 2011; Swanson, 2015).

Traditionally, changes in food consumption over the course of the year would primarily have been driven by the seasonal variations in the availability of specific foods (e.g., Brug, Debie, van Assema, & Weijts, 1995). The timing of the harvest would thus traditionally have been an extremely important marker determining the availability of many foods (Westerterp-Platenga, 1999). Nowadays, of course, in many westernized markets, the majority of foods are available year-round meaning that any residual seasonal changes must have a more cultural/ritual, climatic/physiological, and/or possibly also psychological explanation instead (though price variations for in- versus out-of-season produce should not be forgotten either; Valpiani, Wilde, Rogers, & Stewart, 2015). Indeed, as Kräuchi and Wirz-Justice (1988, p. 323) note: *"Although humans consider themselves to be largely independent of the seasons, there is now a great deal of evidence for seasonal rhythms in psychological dimensions, emotional states, and physiological, neurochemical, and hormonal measures (for review: Aschoff, 1981; Lacoste and Wirz-Justice, 1989)."*

For instance, according to Shephard and Aoyagi (2009), evolutionary responses to shorter days and colder temperatures in winter may be responsible for seasonal weight changes, including a biologically mediated decrease in physical activity in order to reduce energy expenditure. As we will see later, though, any seasonal changes in diet may be more pronounced in those who happen to suffer from Seasonal Affective Disorder (SAD; Kräuchi & Wirz-Justice, 1988), as well as in those living in more extreme environments (e.g., Marriot & Carlson, 1996; Westerterp-Platenga, 1999). Those individuals suffering from SAD have, for instance, been reported to increase their consumption of carbohydrate-rich foods in winter (so-called 'carbohydrate craving') while showing a reduced intake during the summer months.

The majority of the world's population now lives an urban existence, spending an estimated 95% of their lives indoors (see Ott & Roberts, 1998; Velux YouGov Report, 2018). As such, it is easy to imagine how seasonal changes (e.g., in weather or light levels) might no longer have quite the same influence over our mood and behaviour that they once did. To the extent that seasonal variations in the pattern of food consumption are maintained currently, that might thus be taken to suggest the importance of food culture and ritualized eating occasions (such as Thanksgiving or Christmas) is sustaining traditional patterns of food consumption. It becomes, in other words, something of an open question as to what proportion of the seasonal variations in the pattern of food consumption that are still evident nowadays reflect a purely social phenomenon (i.e., explainable in terms of culture/ritual, and human psychology) versus any climatic/physiological factors that may once have played a much more important role in determining what we ate, and when we ate it.

Intriguingly, however, significant changes in food odour hedonics and familiarity ratings have been reported over the course of the year, especially in those countries with marked seasonal changes in climate (e.g., Ristic, Danner, Johnson, Meiselman, Hoek, Jiranek, et al., 2019; Seo, Buschhüter, & Hummel, 2009). Ultimately, I would like to propose that the more-or-less subtle seasonal changes in our preference for particular sensory food cues, can be explained, at least in part, by means of a multisensory extension of what has come to be known as the ‘ecological valence theory’ of colour preference (e.g., Palmer & Schloss, 2010; Schloss & Heck, 2017).

Hence, while those with access to increasingly globalized food marketplace can get hold of more foods than ever throughout the year (i.e., regardless of the season), there nevertheless appears to be a strong drive/appeal for at least some degree of seasonal variation in the foods and drinks that we choose to consume (see Fjeld & Sommer, 1982, for increased seasonal produce purchased from those who shop at farmers’ markets; Wilkins, 1995, 1996). Below I will take a closer look at the various explanations that have been put forward to account for such patterns (e.g., in terms of culture, marketing, psychology, and physiology). First, though, I briefly review the evidence concerning the seasonal differences in the purchase/consumption of food and drink that have been documented to date.

2. Seasonal/annual changes in the pattern of food consumption

Analysis of food diaries clearly shows that both what we choose to eat, not to mention how much, is influenced by the time of year (e.g., Van Staveren, Deurenberg, Burema, DeGroot, & Hautvast, 1986; Zifferblatt, Wilbur, & Pinsky, 1980). In fact, the evidence highlights various differences in people’s food preference, and food behaviour, depending on where in the world they happen to live, as a function of the season, or time of year (e.g., Capita & Alonso-Calleja, 2005; Joachim, 1997a, b; Prasad, Lumia, Erkkola, Tapanainen, Kronberg-Kippilä, Tuokkola, et al., 2010; Subar, Frey, Harlan, & Kahle 1994). Perhaps unsurprisingly, seasonal variations in the pattern of food consumption tend to be more noticeable in those places (e.g., temperate climates) where the seasonal variation in climate is more pronounced. According to one study, conducted almost two decades ago, top of mind amongst North American consumers for seasonal food products were fruits and vegetables, whereas staple foods such as meat, bread, and cereals were mentioned as non-seasonal food items (Wilkins, Bowdish, & Sobal, 2000, 2002).[1]

In one small pilot study, Joachim (1997b) documented differences in self-reported food consumption in summer (N = 16 participants) versus winter (N = 27 participants). Of the 117 foods evaluated in this particular food frequency questionnaire, 89% showed a difference between summer and winter consumption. Meanwhile, Capita and Alonso-Calleja (2005) conducted a diary food study in Spain with 303 individuals aged between 19-40 yrs. Their results revealed that daily total food consumption was higher in the winter than in summer in males. What is more, a higher average intake of energy (men), and a large number of nutrients (both men and women), were observed in the winter months. A significantly higher consumption of most fruits and vegetables, as well as some milk products was also observed in the winter months. Overall, the results of this relatively small study suggest that the quantity of food consumed by Spanish males varies over the course of the year, while seasonal change in the density of nutrients were more apparent in the females who chose to take part in this study.

Elsewhere, Van Staveren et al. (1986) documented a somewhat lower fat consumption in the summer months (37.2% energy vs. 39.4% in winter) in a small sample of students tested in The Netherlands. In particular, the latter researchers assessed 114 women (29-32 years old), with food consumption being estimated once monthly, using the 24 hr recall method (see also Carter, Lewington, Piernas, Bradbury, Key, Jebb, et al., 2019). A seasonal variation in the consumption of macronutrients has been reported in several studies (e.g., Van Staveren et al., 1986; Zifferblatt et al., 1980). Van Staveren and colleagues also documented an annual fluctuation in

[1] Seasonal foods have been defined by DEFRA (2012) as: *'food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It needs not necessarily be consumed locally to where it is grown'.* Meanwhile, according to Macdiarmid (2014, p. 368): *"Seasonality can be defined as either globally seasonal (i.e. produced in the natural production season but consumed anywhere in the world) or locally seasonal (i.e. produced in the natural production season and consumed within the same climatic zone)."*

people's weight (of <1Kg), being higher before winter, and dropping before summer. Indeed, significant changes in people's weight over the course of the year tend to be more pronounced in those countries that are considered less developed (e.g., Kigutha, van Staveren, Wijnhoven, Hautvast, & Bentley, 1995; Prentice, Whitehead, Roberts, & Paul, 1981; van Staveren et al., 1986). Though, that said, it is important to note that by no means all studies have documented a seasonal variation in people's total energy intake (e.g., see Behall, Scholfield, Hallfrisch, Kelsay, & Reiser, 1984; Van Staveren et al, 1986; Zifferblatt et al., 1980).

In one of the largest studies of its kind, Sturm, Patel, Alexander, and Paramanund (2016) examined seasonal cycles in food purchases and changes in body mass index (BMI) amongst South Africans participating in a health promotion programme over a four-year period from 2009-2013. These researchers studied the relationship between seasonality in food purchases and BMI by analysing food purchases using supermarket scanner data for about 400,000 South African households (including individual surveys from an overlapping population of about 500,000 individuals). The results (see **Figure 1**) revealed that unhealthy food spending (e.g., on sugar-sweetened beverages, candy, ice cream, etc.) was highest in December, followed by a sharp reversal in January (with an increase in the sales of fruit/vegetables, whole grains, non-fat dairy, etc.). It is already worth highlighting here how the documented increase in unhealthy food purchases in the month of December, followed by weight gain in this South African study, would point to social (i.e., ritual/cultural/psychological) rather than biological reasons (e.g., related to cold dark winters) for behaviours that are counterproductive to public health in a modern environment (cf. Shephard & Aoyagi, 2009).

INSERT FIGURE 1 ABOUT HERE

Another informative study by Stelmach-Mardas, Kleiser, Uzhova, Peñalvo, La Torre, Palys, et al. (2016) involved a systematic review and meta-analysis of 26 published studies that had examined the seasonality of different food groups and the total energy intake. In this case, the articles were split according to whether data was reported on four seasons (winter, spring, summer and autumn) versus only two (i.e., pre-and post-harvest). Meta-analysis of four of the studies highlighted a number of changes in food consumption across the four seasons. In particular, the results revealed that the consumption of fruits declined from winter to spring, while the consumption of vegetables, eggs, and alcoholic drinks increased. From spring to summer, the consumption of vegetables further increased whereas the consumption of cereals decreased. From summer to autumn, the consumption of fruits and cereals increased while the consumption of vegetables, meat, eggs, and alcoholic drinks decreased. Finally, the transition from autumn to winter resulted in a decrease in the consumption of cereals.

The results of Stelmach-Mardas et al.'s (2016) meta-analysis also highlighted a significant association between energy intake and season, for 13 of the studies that reported energy intake across four seasons (favouring winter) and for eight studies across pre- and post-harvest seasons (favouring post-harvest). The winter or the post-harvest season is associated with increased energy intake. The intake of fruits, vegetables, eggs, meat, cereals and alcoholic beverages follows a seasonal pattern of consumption. According to Stelmach-Mardas et al., the season was the major determinant of intake for these foods.

2.1. Interim summary

In summary, the evidence reviewed in this section would appear to suggest that despite the increasing availability of many food products on a seemingly permanent basis throughout the course of the year, there are nevertheless still some modest seasonal differences in what people choose to buy/consume (Stelmach-Mardas et al., 2016), that leads to modest annual changes in BMI (Sturm et al., 2016). What is more, many consumers still appear to maintain an association between seasonality and fresh produce (Wilkens et al., 2000, 2002), and, at least in certain markets, Such temporal patterns of consumption are evident not only in developing countries (and rural markets, Locke, Coronado, Thompson, et al., 2009), but also in many developed countries that have wide access to foods on a year-round basis.

Having established the existence of such robust seasonal differences in the consumption of food and drink, the next question to ask is what the explanation(s) for such temporal variability in patterns of food and beverage consumption may be. At the outset, here, one might consider whether seasonal changes in climate/environmental conditions might impact the perception and/or needs of consumers. Alternatively, however, some part of our consumption habits (e.g., for specific foods) are likely driven by culture and ritual (Ratcliffe, Baxter, & Martin, 2019), not to mention advertising/marketing interventions (see Axelson, 1986; Waldrop & Mogelonsky, 1992). After all, ritualistic celebrations such as Thanksgiving (predominantly in The States; Wallendorf & Arnould, 1991), Christmas, or New Year in many parts of the world (e.g., 'Washoku, traditional dietary cultures of the Japanese, notably for the celebration of New Year', 2020), would seem to provide the food marketers with some excellent opportunities to promote specific foods that may differ from the typical fayre that is consumed during the rest of the year. Relevant here, it has been reported that sales of ready-to-eat cereal fall by 10-20% during the week before, or the week of, the Thanksgiving and Christmas holidays in The States, while sales of piecrust increase by anywhere from 50-225% (Totten, 1991; see also Hull, Radley, Dinger, & Fields, 2006). At the same time, however, it is worth noting how the temptation to splurge on unhealthy food and drink at Christmas has also been reported to trigger a desire to make-up by purchasing more healthy foods (and so allow people to make a fresh start) in the New Year (Pope et al., 2014). Note that this was precisely the pattern of behaviour demonstrated so clearly in Stelmach-Mardas et al.'s (2016) meta-analysis.[2]

Certainly, the role of food marketing should not be underestimated as far as the promotion of seasonal foods is concerned (e.g., Bry, 2015; Danziger, 2017). For instance, the ubiquity of spiced-pumpkin at Thanksgiving in North America can sometimes feel like little more than an example of extremely successful marketing (e.g., by the likes of Starbucks). Over time, such marketing-led interventions may become increasingly well accepted as seasonal flavours through a process of associative conditioning. Here, though, one might also consider the traditional incorporation of Brussels sprouts into Christmas meals in the UK. The presence of this divisive vegetable (given its bitter taste) in the traditional Christmas meal makes sense inasmuch as this vegetable would have been harvested (and hence available for consumption) in Europe in November (i.e., and hence be ready for the Christmas dining table). Certain of the traditional foods that are associated with specific times of year can therefore be seen as cementing seasonal variations in the availability of different foods that would once have been far more apparent (Waddington, 2006). It is, though, important to note that not all such traditional foods can be so explained (think only of turkey at Christmas in many western countries).

3. Seasonal/climatic changes in consumer psychology

In many parts of the world, the barometric air pressure, ambient temperature, and/or humidity change in a more-or-less predictable manner over the course of the year. However, the effects of natural variations in various atmospheric indicators on chemosensory perception tend to be

[2] Note that a similar trend toward increased sales of healthy salad items has also been documented on Mondays, the suggestion being that people are attempting to make up for their overindulgence at the weekend (Cohen, 2011).

relatively modest and inconsistent at best (e.g., Kuehn, Welsch, Zahnert, & Hummel, 2008; Philpott, Goodenough, Passant, Robertson, & Murty, 2004). As such, the changes in atmospheric conditions that are often experienced over the course of the year (and, in particular, any associated changes in chemosensory perception) fail to provide an obvious explanation for why the foods we choose to consume at different times of year should change with the seasons. Indeed, it is worth noting that the changes in food consumption documented in those operating under extreme environmental conditions (e.g., military personnel) tend primarily to be in terms of modest variations in the total amount of energy consumed (i.e., quantitative differences), rather than necessarily in terms of qualitative differences in terms of what is consumed (e.g., see Ahmed, Mandic, Lou, Goodman, Jacobs, & L'Abbé, 2019).

In the Northern hemisphere, the summer months tend to be much warmer than the winter. In terms of possible seasonal changes in taste resulting from such fluctuations in ambient temperature, some of the only relevant published data comes from Shannon (1966). He studied salivary flow in almost 4,000 young males (17-22 yrs) at a military base in San Antonio, Texas, over the course of a year. A small, but nevertheless still significant, decline in parotid salivary flow that Shannon put down to increased dehydration was evidenced during the hotter summer months (May-August). It would, though, seem unlikely that the very modest reduction observed in this early study would have been large enough to have had a significant effect on taste perception (see Spence, 2011, for a review, of the role of saliva in multisensory flavour perception). According to laboratory-based research from Japan, a sudden increase in ambient indoor temperature from 23-28°C can result in a decreased preference for savoury foods (Motoki, Saito, Nouchi, Kawashima, & Sugiura, 2018). It is, though, unclear whether the more gradual changes in ambient outdoor temperature that take place over the course of the year would necessarily have a similar effect on our food choices/preferences. Indeed, the available sales data (at least here in the UK) tends to suggest the opposite may be the case.

For example, according to a news report regarding Tesco's policy for resupplying their UK stores: *"A ten degree rise on a summer weekend can mean customers want 300 per cent more barbecue meat and 50 per cent more coleslaw – but demand for green vegetables will fall by 25 per cent. Cold weather sees sales of cauliflower soup, longlife milk, sausages and root vegetables soar."* (Cohen, 2011). Cohen goes on to state that: *"As soon as it turns bitterly cold, hot chocolate and bird feed fly off the shelves. Whereas the first hot weekend can see strawberry sales increase by 20 per cent."* Of course, it is important to note here that our response to temperature/weather changes is very much relative, depending on where in the world we happen to live, and the normal climatic conditions that we have come to expect there (see Swanson, 2015).[3] Weather-event related effects, such as, for example, the 42% increase in sales of hamburgers as people in the UK start to barbecue as the outside temperature rises from 68 to 75°F (Cohen, 2011), can presumably accumulate and so become evident as seasonal variations in the patterns of food consumption.

Here, though, it is important to note that the world's growing urban population spend most of their lives indoors (e.g., Ott & Roberts, 1998; Velux YouGov Report, 2018).[4] What this means, in practice, is that most of us are exposed to a more stable indoor thermal environment than would previously have been the case when we spent more of our lives were outdoors. In fact, the evidence suggests that, average indoor temperatures have not only increased significantly over recent decades, but have also become much less variable over the course of the day/year (Mavrogianni, Johnson, Ucci, Marmot, Wardle, Oreszczyn, & Summerfield, 2013).[5] Remarkably, Just, Nichols, and Dunn (2019) recently highlighted how the thermostat in most North American homes appears to match the temperature/humidity of the Ethiopian highlands where we evolved more closely than any other geographic/climatic region.

Spending so much of our lives indoors has been associated with a marked increase in SAD, a mild form of depression, in the winter months amongst those living in the Northern hemisphere (see Rosenthal, 2019, for a recent review of SAD). In particular, the chronic shortage of natural light in the winter months at greater latitudes can all too easily end-up depressing those who rarely make it outside during the few hours of daylight. To give some sense of the scale of the problem, it has been estimated that as many as two million workers in Manhattan alone suffer from the negative consequences of light hunger during the winter (Terman, 1989). Such seasonal changes in mood (Murray, Allen, & Trinder, 2001; Nayyar & Cochrane, 1996), often linked to the reduced exposure to natural light (e.g., Thorn, Hucklebridge, Evans, & Clow,

---

[3] Note here that there may also be important psychological differences between equivalent changes in indoor and outdoor temperature.

[4] The proportion of the world's population living an urban existence continues to grow year-on-year. In fact, as of 2010, more people around the globe lived in cities than in rural areas, and it has been estimated that by 2050 60% of the world's population will be urban (see UN-Habitat, 2010; United Nations Department of Economic and Social Affairs, 2018).

[5] As architect Lisa Heschong (1977, p. 20) notes in her book *Thermal delight in architecture*: *"The technology of heating and cooling aims … to achieve a thermal 'steady-state' across time and a thermal equilibrium across space."*

2009), might well be expected to change the patterns of food choice/consumption that are documented during the dark winter months.

It is certainly possible to imagine the incidence of comfort eating increasing amongst those whose mood is lower during the dark winter months. At the same time, however, it should also be noted that the emotional triggers for comfort eating (namely, feeling emotionally threatened; see Spence, 2017b) do not necessarily match up with the conditions giving rise to SAD. That being said, some researchers have highlighted the shared associations that exist between binge eating and seasonality (e.g., Davis, 2013). And, according to a 2015 article published in *The Washington Post*: *"If you find yourself reaching for heartier and richer foods as the temperature drops, you're not the only one. Google's data show that Internet searches for pork chops, meatballs, chocolate chip cookies, apple streusel, French toast and other comfort foods spike during the winter and when blizzards occur."* (Swanson, 2015).

Indeed, Swanson (2015) goes on to note how the food industry is increasingly seizing on such weather-related cravings by means of more targeted advertising (see also Kinnucan & Forker, 1986). So, for example, the Campbell Soup Co. apparently tracks when the weather takes a turn for the worse in major U.S. cities, and deliberately schedules more soup ads in those markets. Meanwhile, in 2015, McDonald's announced that it was going to begin using digital menu boards that offered the possibility of changing the offerings on display based on the local weather conditions (Peterson, 2015). The latter announcement leading Swanson (2015) to suggest that: *"when it's hot outside, expect to see McFlurries; when it's cold, heartier meals and hot beverages."*

While a number of the effects that have just been discussed are linked to more granular changes in the weather (i.e., to specific weather events, such as severe storms or unexpected bouts of sunshine), to the extent that such events are not evenly distributed over the course of the year, their aggregated effect may be expected to be evidence at the level of seasonal patterns of food consumption too.

3.1. Interim summary

Predictable changes in climate/atmosphere, and consequently on our mood/behaviour, over the course of the year likely once contributed to seasonal differences in the pattern of food that our predecessors would have consumed. However, the fact that the majority of the world's population now lives an essentially urban existence, with an estimated 95% of people's time being spent indoors (Ott & Roberts, 1998; Velux YouGov Report, 2018), in temperature-controlled environments that are themselves less variable than they were even just a few decades ago (Mavrogianni et al., 2013) likely reduces the influence of any seasonal changes in outdoor climatic and atmospheric conditions on our (food) behaviour. That said, the limited exposure to natural light in the winter months in many Northern countries has been shown to exert a negative effect on people's mood that may be expected to lead, or so it has been suggested, to an increase in the consumption of comfort foods (Swanson, 2015).[6] Having assessed the influence of seasonal differences in climatic/atmospheric factors on our food choices, I next want to take a look at recent evidence suggesting that our perception of the sensory-discriminative and hedonic aspects of food aromas may actually exhibit some meaningful seasonal variation.

4. Seasonal changes in flavour/aroma perception

It does not, I think, seem to (m)any of us that foods taste different at different times of year. And yet, at the same time, many of us find ourselves craving specific foods at particular times of the year. In support of such the former intuition, Postolache, Wehr, Doty, Sher, Turner, Bartko, et al. (2002) reported no significant differences in people's odour sensitivity between summer and winter. By contrast, however, Goel and Grasso (2004) demonstrated that young men and women (N = 169) exhibited a significantly enhanced ability to discriminate between pairs of odour during the fall (by c. 8%) as compared to during the winter/spring (with performance intermediate in the summer months). However, given that only a single odorant (lavender) was presented in this study, it is difficult to know whether the seasonal changes reported reflect a general change in olfactory sensitivity, or rather perhaps something much more stimulus-specific (cf. Seo et al., 2009; Wada, Inada, Yang, Kunieda, Masuda, Kimura, Kanazawa, & Yamaguchi, 2012). What is more, while lavender is often described as a non-food odour (at least by a number of sensory scientists who, one would think, should know better), it is actually one of the key components in the popular 'herbes de Provence' mix

[6] And, of course, for those who are able to get out during the course of the day, pleasant weather (higher temperature and barometric pressure) are likely to have a more pronounced effect our mood and cognition (Keller, Fredrickson, Ybarra, Cote, Johnson, Mikels, et al., 2005).

(McGee, 2004, p. 403). The distinctive flavour of this herb is itself sometimes found in other foods, such as, for example, biscuits. That said, the scent of this seasonal plant is more commonly experienced in nature, and in fragranced products, than in food, hence its status as a seasonal flavour is somewhat ambiguous (Mitchell, Konigsbacher, & Edman, 1964; cf. Trivedi, 2006).

There have been a number of reports of seasonal differences in hedonic and familiarity ratings of olfactory stimuli, as well as seasonal changes in people's preferences for various odours (e.g., Postolache et al., 2002; Ristic et al., 2019). For instance, in one intriguing study, Wada et al. (2012) reported that 6-8 month old Japanese infants exhibited a significant preferential looking bias toward a picture of strawberries (vs. a picture of tomatoes) when in the presence of a congruent in-season strawberry smell (cf. Schwieterman, Colquhoun, Jaworski, Bartoshuk, Gilbert, Tieman, et al., 2014). Intriguingly, however, no such preferential looking bias was reported when these researchers repeated their study with a new group of infants outside of the season for growing strawberries in Japan.

Meanwhile, according to research from Seo et al. (2009), people tend to rate the odour of cinnamon as more familiar and pleasant during the Christmas season than during the summertime (at least in the German participants who were tested in this particular study; cf. Ayabe-Kanamura, Schicker, Laska, Hudson, Distel, Kobayakawa, & Saito, 1998). In an initial test of 100 adults, the odours of orange, cinnamon, and cloves, were all associated with Christmas (especially cinnamon), whereas the aroma of rose and pineapple were all associated with the summertime instead. Twelve odorants were then presented to different groups of participants either in the summertime (August, N = 41 participants) or else during the Christmas season (N = 51 participants, all tested in the science museum in Dresden, Germany). The participants rated the scent of orange, cinnamon, liquorice, clove, and rose as significantly more familiar at Christmas time, whereas those tested in the summer rated the odour of banana and coffee as more familiar instead. In terms of the participants' hedonic ratings, the cinnamon, pineapple, and rose odours were all rated significantly higher at Christmas than during in summertime. Intriguingly, however, none of the odorants chosen for this particular study was rated hedonically higher during the summer than in the winter.

In a more recent study, Ristic and colleagues (2019) verbally evoked each of the four seasons (spring, summer, autumn, and winter) in an online survey of 3,000 regular wine consumers from Australia, the USA, and the UK. The participants were instructed to report their preferred wine-related aromas, from amongst the following nine: Strawberry, mint, chocolate, confectionary, passionfruit, black pepper, lemon, rose, and barnyard). Ristic et al.'s results revealed that those wines that were rich in chocolate notes tended to be preferred in the winter months (24%), whereas those wines expressing notes of strawberry, passionfruit, lemon, and rose were preferred in the summer instead (20-32%). By contrast, expressed preferences for specific wine aromas were much weaker for the other two (verbally-evoked) seasons, with less than 11.5% of participants suggesting lemon and rose for the spring, and less than 10% putting forward chocolate and pepper for the autumn months.

As hinted at by Seo et al.'s (2009) results, certain times of year would therefore appear to be associated with particular sensory cues, think Thanksgiving in North America, or Christmas in many parts of the world.[7] Amongst the sensory associations that many North Americans have with Thanksgiving are golden fall colours (e.g., in New England, as well as on the Eastern seaboard of China; e.g., see Ackerman, 2000, pp. 257-260), as well as a prominent presence of cinnamon/spiced pumpkin olfactory notes (e.g., Bry, 2015; Danzinger, 2017). Fiery orange foods, such as pumpkin, sweet potatoes, carrots, and butternut squash also tend to be much more visible in the autumn too (Bry, 2015).

Chefs, and other culinary professionals, sometimes recommend the use of seasonal colours in dishes – think here only of green for spring, and a golden yellow and orange for summer (Lightner & Rand, 2014). Such an approach to food design makes a lot of sense in terms of ecological valence theory (Schloss & Heck, 2017). In particular, according to Palmer and Schloss (2010), our stimulus preferences (specifically our colour preferences) arise from our average affective responses to the various stimulus-associated objects that we happen to come across. According to Karen Schloss and her colleagues, this theory can be used to help explain seasonal changes in our liking for different colours, such as, for example, a preference for dark-warm colours (think dark-red, brown, olive, and dark-chartreuse) during the fall relative to other seasons – since the latter colours may be linked to the changing colour of leaves in nature (Schloss & Heck, 2017; Schloss, Nelson, Parker, Heck, & Palmer, 2017). And while ecological valence theory was developed in the context of trying to explain (changes in) our colour preferences, it might well be argued that there is little reason why the approach could not be

[7] Not only does our liking for the sensorially familiar attributes of seasonal produce increase, but our interpretation of ambiguous perceptual stimuli may, in some rare cases, also change as a function of the time of year at which they happen to be presented (see Brugger & Brugger, 1993).

extended to incorporate our seasonally-changing preferences for a variety of other sensory cues too, such as, for example, in-season aromas (cf. Seo et al., 2009; Wada et al., 2012). After all, seasonal food aromas, just like fall leaf colours, are more commonly experienced at certain times of year than at others (see also Cappucci, 2018), and hence may be more preferred at that time of year simply because they happen to be more available.

To the extent that our preferences for food-related sensory stimuli change as a function of the season (or time of year), it would presumably make sense for chefs to integrate a seasonal element into their product offerings. At the same time, however, it is also worth noting how seasonal differences in the appearance of various food products have sometimes been eliminated in order to provide consumers with a consistent product throughout the year. Indeed, a number of processed branded foods, as well as more natural (and less highly-processed) products strive for consistent ‘optimal’ appearance – be it an orange (rather than green), orange or a yellow (rather than red) banana (see Hisano, 2019, for a review). Consider here only how butter naturally has a golden colour in the summertime, while taking on a much paler colour in the winter in the Northern hemisphere. For hundreds of years, colouring (annatto) has been deliberately added to butter in order to help give this product a consistent golden yellow colour throughout the year (see Hisano, 2019).

On the one hand, therefore, while seasonal variation undoubtedly has a place, and is seemingly appreciated by consumers, it is also interesting to consider which of our food-related sensory preferences show such seasonal variation. One might also wonder whether our desire for seasonal variety perhaps play to some fundamental craving for variety (that the marketers are only too happy to emphasize with their increasingly-sophisticated data-driven seasonal promotions). Or perhaps it is more a case of seasonal differences in food availability being more acceptable than seasonal changes in the appearance of food products. The latter may perhaps be a little harder for consumers to stomach, or at least so the food marketers would seem to believe.

5. Conclusions

The research that has been reviewed here clearly demonstrates that there are some subtle seasonal differences in the appropriateness of different foods, as well as somewhat more pronounced differences in our food aroma/flavour preferences and food consumption behaviours as a function of the time of year (Ristic et al., 2019; Seo et al., 2009). In those parts of the world with more of a seasonal climate, these differences may well be influenced by seasonal changes in the weather. At the same time, however, the role of seasonality on the availability of raw ingredients, leading to changes in familiarity/liking for specific food aromas should not be ignored either (Schloss & Heck, 2017; Seo et al., 2009; Wada et al., 2012). And while our increasingly indoor urban existence means that the majority of us are likely to be less influenced by changes in atmospheric/climatic conditions than we once were in the past, nevertheless both weather- related and seasonal changes in consumption are still evident in our contemporary food behaviours. As we have seen at several points throughout the manuscript, the food marketers would appear to be encouraging such seasonality, often building on cultural/ritual associations between specific foods at particular times of year (with the latter often emerging out of traditional seasonal variations in the availability of specific foods). At the same time, however, many stores (especially in highly developed countries) appear to be stocking a wider range of food produce on a year-round basis. That said, it has been suggested that eating more seasonal food might itself help to contribute to people's health, not to mention potentially supporting environmental sustainability (Cox, Whichelow, & Prevost, 2000; Macdiarmid, 2014).

Ultimately, therefore, it would seem as though the seasonal marketing of food is becoming increasingly popular at the same time as (or perhaps in response to the fact that) the food system in the developed world has increasingly eliminated seasonality from determining what food we can buy when (cf. Spence, 2020).

REFERENCES

Ackerman, D. (2000). *A natural history of the senses*. London, UK: Phoenix.

Ahmed, M., Mandic, I., Lou, W., Goodman, L., Jacobs, I., & L'Abbé, M. R. (2019). Comparison of dietary intakes of Canadian Armed Forces personnel consuming field rations in acute hot, cold, and temperate conditions with standardized infantry activities. *Military Medicine Research*, **6**:26. https://doi.org/10.1186/s40779-019-0216-7.

Allen, V. (2016). Why women eat more at that time of the month: Change in hormone levels can lead to women consuming up to 500 extra calories. *Daily Mail Online*, **October 31st**. https://www.dailymail.co.uk/health/article-3888366/Why-women-eat-time-month-Change-hormone-levels-lead-women-consuming-500-extra-calories.html.

Aschoff, J. (1981). Annual rhythms in man. In J. Aschoff (Ed.), *Handbook of the behavioural neurobiology. Vol. 4. Biological rhythms* (pp. 475-487). New York, NY: Plenum Publishing Corporation.

Axelson, M. L. (1986). The impact of culture on food-related behavior. *Annual Review of Nutrition*, **6**, 345-363.

Ayabe-Kanamura, S., Schicker, I., Laska, M., Hudson, R., Distel, H., Kobayakawa, T., & Saito, S. (1998). Differences in perception of everyday odors: A Japanese-German cross-cultural study. *Chemical Senses*, **23**, 31-38.

Behall, K. M., Scholfield, D. J., Hallfrisch, J. D., Kelsay, J. L., & Reiser, S. (1984). Seasonal variation in plasma glucose and hormone levels in adult men and women. *American Journal of Clinical Nutrition*, **40**, 1352-1356.

Brug, J., Debie, S., van Assema, P., & Weijts, W. (1995). Psychosocial determinants of fruit and vegetable consumption among adults: Results of focus group interviews. *Food Quality and Preference*, **6**, 99-107.

Brugger, P., & Brugger, S. (1993). The Easter Bunny in October: Is it disguised as a duck? *Perceptual & Motor Skills*, **76**, 577-578.

Bry, D. (2015). Orange is the new yuck: Why autumn foods make me sick. *The Guardian*, **October 1st**. http://www.theguardian.com/lifeandstyle/2015/oct/01/why-orange-food-is-disgusting-pumpkins-carrots.

Capita, R., & Alonso-Calleja, C. (2005). Differences in reported winter and summer dietary intakes in young adults in Spain. *International Journal of Food Sciences and Nutrition*, **56(6)**, 431-443.

Cappucci, M. (2018). The scent of a season: Explaining the aromas of fall. *The Washington Post*, **October 19th**. https://www.washingtonpost.com/weather/2018/10/19/scent-season-explaining-aromas-fall/.

Carman, H. F., & Figueroa, E. E. (1986). An analysis of factors associated with weekly food store sales variation. *Agribusiness*, **2(3)**, 375-390.

Carter, J. L., Lewington, S., Piernas, C., Bradbury, K., Key, T. J., Jebb, S. A., Arnold, M., Bennett, D., & Clarke, R. (2019). Reproducibility of dietary intakes of macronutrients, specific food groups, and dietary patterns in 211 050 adults in the UK Biobank study. *Journal of Nutrition Science*, **8**:e34. doi: 10.1017/jns.2019.31.

Cohen, T. (2011). Here is the shopping forecast: How supermarkets use weather predictions to decide what to stock. *Daily Mail Online*, **August 16th**. https://www.dailymail.co.uk/news/article-2026439/Supermarkets-use-weather-predictions-decide-stock.html.

Cornelissen, G., Singh, R. B., Schwartzkopff, O., & Halberg, F. (2013). Chronobiology and chronomics honor Douglas Wilson. Neither calories nor anything else are equal at breakfast and dinner or along other time scales. *The Open Nutraceuticals Journal*, **6 (Suppl 1: M7)**, 89-104.

Cox, B. D., Whichelow, M. J., & Prevost, A. T. (2000). Seasonal consumption of salad vegetables and fresh fruit in relation to the development of cardiovascular disease and cancer. *Public Health Nutrition*, **3(1)**, 19-29.

Danziger, P. N. (2017). Retailers, time to brand your store with a signature scent -- Pumpkin spice, anyone? *Forbes*, **September 21st**. https://www.forbes.com/sites/pamdanziger/2017/09/21/retailers-time-to-brand-your-store-with-a-signature-scent-pumpkin-spice-anyone/.

Davis C. (2013). A narrative review of binge eating and addictive behaviors: Shared associations with seasonality and personality factors. *Frontiers in Psychiatry*, **4**:183. DOI=10.3389/fpsyt.2013.00183.

de Castro, J. M. (1991). Weekly rhythms of spontaneous nutrient intake and meal pattern of humans. *Physiology & Behavior*, **50**, 729-738.

DEFRA (2012). Understanding the environmental impacts of consuming foods that are produced locally in season. *Project FO0412*. http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=16390.

Fjeld, C. R., & Sommer, R. (1982). Regional-seasonal patterns in produce consumption at farmers' markets and supermarkets. *Ecology of Food and Nutrition*, **12**, 109-115. DOI: 10.1080/03670244.1982.9990703.

Goel, N., & Grasso, D. J. (2004). Olfactory discrimination and transient mood change in young men and women: Variation by season, mood state, and time of day. *Chronobiology International*, **21**, 691-719.

Heschong, L. (1979). *Thermal delight in architecture*. Cambridge, MA: MIT Press.

Hisano, A. (2019). *Visualizing taste: How business changed the look of what you eat*. Harvard: Harvard University Press.

Hull, H. R., Radley, D., Dinger, M. K., & Fields, D. A. (2006). The effect of the Thanksgiving holiday on weight gain. *Nutrition Journal*, **5**, 1-6.

Joachim, G. (1997a). Supply and demand: A framework for explaining variability in dietary intake and its impact on data. *Nutrition and Health*, **11**, 289-299.

Joachim, G. (1997b). The influence of time on dietary data: Differences in reported summer and winter food consumption. *Nutrition and Health*, **12(1)**, 33-43.

Just, M. G., Nichols, L. M., & Dunn, R. R. (2019). Human indoor climate preferences approximate specific geographies. *Royal Society Open Science*, **6(3)**:180695 DOI: 10.1098/rsos.180695.

Keller, M. C., Fredrickson, B. L., Ybarra, O., Cote, S., Johnson, K., Mikels, J., Conway, A., & Wager, T. (2005). A warm heart and a clear head. The contingent effects of weather on mood and cognition. *Psychological Science*, **16**, 724-731.

Kigutha, H. N., van Staveren, W. A., Wijnhoven, T. M., Hautvast, J. G., & Bentley, G. R. (1995). Maternal nutritional status may be stressed by seasonal fluctuations in food availability: evidence from rural women in Kenya. *International Journal of Food Science and Nutrition*, **46**, 247-255.

Kinnucan, H., & Forker, O. D. (1986). Seasonality in the consumer response to milk advertising with implications for milk promotion policy. *American Journal of Agricultural Economics*, **68(3)**, 562-571.

Kräuchi, K., & Wirz-Justice, A. (1988). The four seasons: Food intake frequency in seasonal affective disorder in the course of a year. *Psychiatry Research*, **25**, 323-338.

Kuehn, M., Welsch, H., Zahnert, T., & Hummel, T. (2008). Changes of pressure and humidity affect olfactory function. *European Archives of Otorhinolaryngology*, **265**, 299-302.

Lacoste, V., & Wirz-Justice, A. (1989). Seasonal variation in normal subjects: An update of variables current in depression research. In N. E. Rosenthal & M. C. Blehar (Eds.), *Seasonal affective disorders and phototherapy* (pp. 167-229). New York, NY: Guilford Press.

Larson, R. B. (1997). Food consumption and seasonality. *Journal of Food Distribution Research*, **28(2)**, 36-44.

Lightner, M., & Rand, S. (2014). The enhancement of natural colors to provoke seasonality. *International Journal of Gastronomy and Food Science*, **2**, 55-59.

Locke, E., Coronado, G. D., Thompson, B., et al. (2009) Seasonal variation in fruit and vegetable consumption in a rural agricultural community. *Journal of the American Dietetic Association*, **109**, 45-51.

Löwik, M. R. H., Hulshof, K. F. A. M., Brussaard, J. H., & Kistemaker, C. (1999). Dependence of dietary intake estimates on the time frame of assessment. *Regulations in Toxicology and Pharmacology*, **30**, S48-S56.

Macdiarmid, J. I. (2014). Seasonality and dietary requirements: Will eating seasonal food contribute to health and environmental sustainability? *Proceedings of the Nutrition Society*, **73(3)**, 368-375. doi: 10.1017/S0029665113003753.

Mavrogianni, A., Johnson, F., Ucci, M., Marmot, A., Wardle, J., Oreszczyn, T., & Summerfield, A. (2013). Historic variations in winter indoor domestic temperatures and potential implications for body weight gain. *Indoor and Built Environment*, **22**, 360-375.

McGee, H. (2004). *On food and cooking: The science and lore of the kitchen* (rev. ed.). New York, NY: Scribner.

Mitchell, M. A., Konigsbacher, K. S., & Edman, W. M. (1964). The importance of odor as a nonfunctional component or odor – A tool of marketing. *Annals of the New York Academy of Sciences*, **116**, 685-691.

Motoki, K., Saito, T., Nouchi, R., Kawashima, R., & Sugiura, M. (2018). The paradox of warmth: Ambient warm temperature decreases preference for savory foods. *Food Quality and Preference*, **69**, 1-9.

Murray, G., Allen, N. B., & Trinder, J. (2001). A longitudinal investigation of seasonal variation in mood. *Chronobiology International*, **18**, 875-891.

Nayyar, K., & Cochrane, R. (1996). Seasonal changes in affective state measured prospectively and retrospectively. *British Journal of Psychiatry*, **168**, 627-632.

Ott, W. R., & Roberts, J. W. (1998). Everyday exposure to toxic pollutants. *Scientific American*, **278 (February)**, 86-91.

Palmer, S. E., & Schloss, K. B. (2010). An ecological valence theory of human color preference. *Proceedings of the National Academy of Sciences of the USA*, **107**, 8877-8882. doi: 10.1073/pnas.0906172107.

Peterson, H. (2015). McDonald's 'smart' menus will recommend food based on the weather. *Business Insider*, **November 11th**. https://www.businessinsider.com/mcdonalds-menus-will-recommend-food-based-on-the-weather-2015-11?utm_source=twitter&utm_medium=socialflow.

Philpott, C., Goodenough, P., Passant, C., Robertson, A., & Murty, G. (2004). The effect of temperature, humidity and peak inspiratory nasal flow on olfactory thresholds. *Clinical Otolaryngology*, **29**, 24-31.

Pope, L., Hanks, A. S., Just, D. R., & Wansink, B. (2014). New Year's res-illusions: Food shopping in the New Year competes with healthy intentions. *PLoS One*, **9**:e110561.

Postolache, T. T., Wehr, T. A., Doty, R. L., Sher, L., Turner, E. H., Bartko, J. J., et al. (2002). Patients with seasonal affective disorder have lower odor detection thresholds than control subjects. *Archives of General Psychiatry*, **59**, 1119-1122.

Prasad, M., Lumia, M., Erkkola, M., Tapanainen, H., Kronberg-Kippilä, C., Tuokkola, J., et al. (2010). Diet composition of pregnant Finnish women: Changes over time and across seasons. *Public Health Nutrition*, **13(6A)**, 939-946.

Prentice, A. M., Whitehead, R. G., Roberts, R. B., & Paul, A. A. (1981). Long-term energy balance in childbearing Gambian women. *American Journal of Clinical Nutrition* **34**, 2790-2799.

Ratcliffe, E., Baxter, W. L., & Martin, N. (2019). Consumption rituals relating to food and drink: A review and research agenda. *Appetite*, **134**, 86-93.

Ristic, R., Danner, L., Johnson, T. E., Meiselman, H. L., Hoek, A. C., Jiranek, V., & Bastian, S. E. P. (2019). Wine-related aromas for different seasons and occasions: Hedonic and emotional responses of wine consumers from Australia, UK and USA. *Food Quality and Preference*, **71**, 250-260. https://doi.org/10.1016/j.foodqual.2018.07.011.

Rosenthal, N. E. (2019). *Winter blues: Everything you need to know to beat Seasonal Affective Disorder*. New York, NY: Guilford Press.

Schloss, K. B., & Heck, I. A. (2017). Seasonal changes in color preferences are linked to variations in environmental colors: A longitudinal study of fall. *i-Perception*, **8**:6. doi: 10.1177/2041669517742177.

Schloss, K. B., Nelson, R., Parker, L., Heck, I. A., & Palmer, S. E. (2017). Seasonal variations in color preference. *Cognitive Science*, **41**, 1589-1612. doi: 10.1111/cogs.12429.

Schwieterman, M. L., Colquhoun, T. A., Jaworski, E. A., Bartoshuk, L. M., Gilbert, J. L., Tieman, D. M., et al. (2014). Strawberry flavor: Diverse chemical compositions, a seasonal influence, and effects on sensory perception. *PLOS One*, **9(2)**:e88446.

Seo, H.-S., Buschhüter, D., & Hummel, T. (2009). Odor attributes change in relation to the time of the year. Cinnamon odor is more familiar and pleasant during Christmas season than summertime. *Appetite*, **53(2)**, 222-225. http://doi.org/10.1016/j.appet.2009.06.011.

Shannon, I. L. (1966). Climatological effects on human parotid gland function. *Archives of Oral Biology*, **11**, 451-453.

Shephard, R. J., & Aoyagi, Y. (2009). Seasonal variations in physical activity and implications for human health. *European Journal of Applied Physiology*, **107**, 251-271.

Sobal, J. (1999). Food system globalization, eating transformations, and nutrition transitions. In R. Grew (Ed.), *Food in global history* (pp. 171-193). Boulder, CO: Westview Press.

Spence, C. (2011). Mouth-watering: The influence of environmental and cognitive factors on salivation and gustatory/flavour perception. *Journal of Texture Studies*, **42**, 157-171.

Spence, C. (2017a). Breakfast: The most important meal of the day? *International Journal of Gastronomy and Food Science*, **8**, 1-6. http://dx.doi.org/10.1016/j.ijgfs.2017.01.003.

Spence, C. (2017b). Comfort food: A review. *International Journal of Gastronomy and Food Science*, **9**, 105-109.

Spence, C. (2017c). *Gastrophysics: The new science of eating*. London, UK: Viking Penguin.

Spence, C. (2020). Gastrophysics: Nudging consumers toward eating more leafy (salad) greens. *Food Quality & Preference*, **80**:103800. https://doi.org/10.1016/j.foodqual.2019.103800.

Spence, C. (submitted). Explaining diurnal patterns of food consumption. *Food Quality & Preference*.

Stelmach-Mardas, M., Kleiser, C., Uzhova, I., Peñalvo, J. L., La Torre, G., Palys, W., Lojko, D., Nimptsch, K., Suwalska, A., Linseisen, J., Saulle, R., Colamesta, V., & Boeing, H. (2016). Seasonality of food groups and total energy intake: A systematic review and meta-analysis. *European Journal of Clinical Nutrition*, **70(6)**, 700-708. doi: 10.1038/ejcn.2015.224.

St. Jeor, S., Guthrie, H., & Jones, M. (1983). Variability in nutrient intake in a 28-day period. *Journal of the American Dietetic Association*, **83**, 155-162.

Sturm, R., Patel, D., Alexander, E., & Paramanund, J. (2016). Seasonal cycles in food purchases and changes in BMI among South Africans participating in a health promotion programme. *Public Health Nutrition*, **19(15)**, 2838-2843. doi:10.1017/S1368980016000902

Subar, A. F., Frey, C. M., Harlan, L. C., & Kahle L. (1994). Differences in reported food frequency by season of questionnaire administration: The 1987 national health interview survey. *Epidemiology*, **2**, 226-233.

Swanson, A. (2015). The hidden ways weather determines what you buy. *The Washington Post*, **November 25th**. https://www.washingtonpost.com/news/wonk/wp/2015/11/25/the-hidden-ways-weather-determines-what-you-buy/.

Terman, M. (1989). On the question of mechanism in phototherapy for seasonal affective disorder: Considerations of clinical efficacy and epidemiology. In N. E. Rosenthal & M. C. Blehar (Eds.), *Seasonal affective disorders and phototherapy* (pp. 357-376). New York, NY: Guilford Press.

Thorn, L., Hucklebridge, F., Evans, P., & Clow, A. (2009). The cortisol awakening response, seasonality, stress and arousal: A study of trait and state influences. *Psychoneuroendocrinology* **34**, 299-306.

Totten, J. C. (1991). Seasonality adjustments for weekly scanner data. Paper presented at the *1991 TIMS Special Interest Conference on Scanner Data* at UCLA. January.

Trivedi, B. (2006). Recruiting smell for the hard sell. *New Scientist*, **2582**, 36-39.

UN-Habitat (2010). *State of the world's cities 2010/2011: Bridging the urban divide*. http://www.unhabitat.org/documents/SOWC10/R7.pdf.

United Nations Department of Economic and Social Affairs (2018). *68% of the world population projected to live in urban areas by 2050, says UN*. **May 16th**. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html.

Valpiani, N., Wilde, P., Rogers, B., & Stewart, H. (2015). Patterns of fruit and vegetable availability and price competitiveness across four seasons are different in local food outlets and supermarkets. *Public Health Nutrition*, **18(15)**, 2846-2854. doi:10.1017/S1368980015000981.

Van Staveren, W. A., Deurenberg, P., Burema, J., DeGroot, L. P. G. M., & Hautvast, J. G. A. J. (1986). Seasonal variation in food intake, pattern of physical activity and change in body weight in a group of young adult Dutch women consuming self-selected diets. *International Journal of Obesity*, **10**, 133-145.

Velux YouGov Report (2018). *The indoor generation: Effects of modern indoor living on health, wellbeing and productivity*. www.velux.nn/indoorgeneration.

Wada, Y., Inada, Y., Yang, J., Kunieda, S., Masuda, T., Kimura, A., Kanazawa, S., & Yamaguchi, M. K. (2012). Infant visual preference for fruit enhanced by congruent in-season odor. *Appetite*, **58(3)**, 1070-1075. doi: https://doi.org/10.1016/j.appet.2012.02.002.

Waddington, P. (2006). *Seasonal food: A guide to what's in season when and why*. London: Transworld Publishers.

Waldrop, J., & Mogelonsky, M. (1992). *The seasons of business: The marketer's guide to consumer behavior*. Ithaca, NY: American Demographic Books.

Wallendorf, M., & Arnould, E. J. (1991). "We gather together": Consumption rituals of Thanksgiving day. *Journal of Consumer Research*, **18**, 13-31.

'Washoku, traditional dietary cultures of the Japanese, notably for the celebration of New Year' (2020). https://ich.unesco.org/en/RL/washoku-traditional-dietary-cultures-of-the-japanese-notably-for-the-celebration-of-new-year-00869.

Westerterp-Platenga, M. S. (1999). Effects of extreme environments on food intake in human subjects. *Proceedings of the Nutrition Society*, **58**, 791-798.

Wilkins, J. L. (1995). Seasonal and local diets: Consumers' role in achieving a sustainable food system. *Research in Rural Sociology and Development*, **6**, 149-166.

Wilkins, J. L. (1996). Seasonality, food origin, and food preference: A comparison between food cooperative members and non-members. *Journal of Nutrition Education*, **28**, 329-337.

Wilkins, J. L., Bowdish, E., & Sobal, J. (2000). University student perceptions of local and seasonal foods. *Journal of Nutrition Education*, **32**, 251-260.

Wilkins, J. L., Bowdish, E., & Sobal, J. (2002). Consumer perceptions of seasonal and local foods: A study in a U.S. community. *Ecology of Food and Nutrition*, **41(5)**, 415-439. DOI: 10.1080/03670240214066.

Young, C. M., Smudski, V. L., & Steele, B. F. (1951). Fall and spring diets of school children in New York State. *Journal of the American Dietetic Association*, **27**, 289-292.

Zifferblatt, S. M., Wilbur, C. S., & Pinsky, J. L. (1980). Understanding food habits. *Journal of the American Dietetic Association*, **76**, 9-14.

Figure 1. Share of unhealthy food purchases (light grey line) and fruit/vegetable purchases (dark grey line) in total food expenditure by month, showing that unhealthy food purchases peak in December, among supermarket purchases by health plan members in South Africa, 2009-2014. Purchases are collapsed into monthly observations, resulting in a total of 7·9 million observations from about 400,000 households [Figure reprinted from Sturm et al. (2016).]