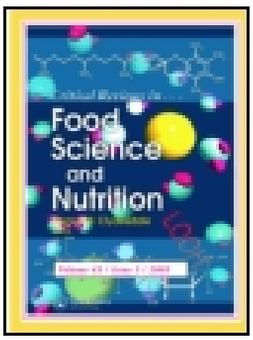

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REVIEW

Factors related to sensory properties and consumer acceptance of vegetables

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ABSTRACT

Many consumers perceive the bitter taste or other sensory characteristic of vegetables as unpleasant, posing a challenge to dietary recommendations aiming to increase vegetable consumption. Food experience is multisensory, with complex interactions between the senses and individual differences in sensory perception. This review focuses on the factors affecting sensory properties of vegetables and sensory perception of vegetables among adults. Topical examples of sensory quality and evaluation of vegetable samples are presented. Cultivar and growing conditions are related to the internal sensory quality of vegetables. The effects of different processing methods, such as freezing and cooking, on the sensory properties of vegetables are also reviewed. Flavor modification of vegetables with seasonings may be used to improve palatability and incorporating vegetables to meals may increase the intake of vegetables. Recently, external factors (e.g. visual and odor stimuli) have been tested in multisensory research in the context of vegetable perception and choice. These options to achieve better sensory quality, more palatable meals and pleasant eating context may be used to promote vegetable intake among adults.

KEYWORDS

Vegetables; taste; flavor; sensory quality; multisensory perception; adults

Introduction

Vegetables and fruits are generally recommended for their health-promoting properties (Aune et al. 2017). However, the consumption of vegetables is low in many countries; for example, in the US, less than 10% of the adult population meet the recommendation for fruit and vegetable intake (Rehm et al. 2016). Various sociodemographic and lifestyle factors, such as gender, age, educational level and smoking, are related to vegetable consumption among adults (Beck et al. 2015; Konttinen et al. 2013; Oliveira, Maia, and Lopes 2014). The patterns of vegetable use and preparation may also be related to local food culture, and regional differences in vegetable and fruit consumption have been reported (Stefler and Bobak 2015). Among adults in the US, more than half of the daily vegetables were consumed at dinner (Moore et al. 2016). In addition to home cooking, increasingly more meals are eaten outside home (Lund, Kjaernes, and Holm 2017). Therefore, the quality of vegetables served in workplace catering and restaurants is essential for vegetable consumption.

This review focuses on sensory aspects in the perception of vegetables from the consumer perspective. Examples of recent studies (mainly since 2010) focusing on the sensory properties and evaluation of vegetables by adult subjects are presented. Many previous reviews have a production or processing technological view on quality factors, and previous reviews have not covered the effects of culinary practices or eating context on the perception of vegetables.

Factors related to the internal sensory properties of vegetables include vegetable cultivar, season and growth conditions. Considering processing factors, different storage, cooking and flavoring options, as well as incorporation of vegetables to meals are reviewed. From the multisensory point of view, some options of external sensory stimuli to modify the perception of vegetables are also highlighted. These factors are dealt with in more detail in the following chapters. The ultimate goal of this review is to present new ideas how these factors could be applied to promote the consumption of vegetables among adults.

Individual differences in sensory perception of vegetables

The perception of food is always multisensory, including all five senses (sense of taste, smell, sight, touch, hearing). All five taste modalities (bitter, sour, sweet, salty, umami) can be perceived in vegetables. Van Stokkom et al. (2016) investigated taste intensities for ten vegetables with different preparation methods (as raw, cooked, mashed and as a cold-pressed juice). They found that most vegetables had low intensities of the five taste modalities, and the preparation methods affected the taste intensity but the effect differed by vegetable type (Van Stokkom et al. 2016). Individual differences in taste perception observed among adults (Hayes, Feeney, and Allen 2013; Monteleone et al. 2017; Chamoun et al. 2018; Puputti et al. 2018) may also be related to the perception of taste modalities in vegetables.

For many consumers, taste and other sensory characteristics of vegetables are challenging. Compared with other core food groups, vegetables are perceived as more bitter and

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harder (Poelman, Delahunty, and de Graaf 2017). People sensitive to specific bitter compounds by phenotype (6-n-propylthiouracil; PROP taster status) or genotype (TAS2R38 genotypes) have been shown to perceive many vegetables as intensely bitter and eat fewer vegetables in general (Duffy et al. 2010; Sandell et al. 2014). On the other hand, Shen, Kennedy, and Methven (2016) reported that bitter taste genotype or phenotype alone could not predict vegetable preference and intake, as demographic factors had a substantial influence. Interestingly, genetic differences in odor perception may also be linked to vegetable consumption. Jaeger et al. (2012) reported that subjects classified as sensitive to the odor of cis-3-hexen-1-ol (green/grassy) tended to consume salad greens and cucumber more frequently.

Visual cues in general are essential determinants of food acceptance, and the color of vegetables relates, for example, to ripeness and freshness (Arce-Lopera et al. 2015). Color hue and saturation were found to impact consumers' expectations about sensory and functional properties of carrots with different colors (Schifferstein, Wehrle, and Carbon 2019). People have been found to differ in their color-flavor associations (Spence et al. 2010) and different consumer segments may be identified based on their color preferences, e.g. in the case of blue potatoes (Paakki, Sandell, and Hopia 2016). In addition, retronasal odor has been shown to have an important role in vegetable liking/disliking (Lim and Padmanabhan 2013). Texture properties are significant for consumers—e.g. firmness in boiled vegetables (Bongoni et al. 2014). Tactile sensitivity and mouthfeel may be related to adult picky eating and acceptance of vegetables (Nederkoorn, Houben, and Havermans 2019). The sense of hearing is rarely considered in the sensory evaluation of foods. However, for example, the crispiness of carrot has been investigated in relation to acoustic signal characteristics (Liu et al. 2015).

In addition to genetic factors and sensory perception, the experience and use of vegetables may depend on other consumer characteristics, such as sociodemographic and lifestyle factors (Beck et al. 2015). Furthermore, attitudes toward healthy food choices may be associated with vegetable intake (Saba et al. 2019). The perception of specific vegetables regarding taste, healthiness, ease of preparation and cost varies significantly across consumer segments (Yi, Kanetkar, and Brauer 2015). Adults may also be neophobic (Knaapila et al. 2015; Laureati et al. 2018) or picky eaters (Zickgraf and Schepps 2016), and these characteristics may contribute to low vegetable consumption also in adulthood. In an Italian study, individual differences in psychological traits, rather than PROP responsiveness, influenced both the preference and consumption of phenol-rich vegetables (De Toffoli et al. 2019). Therefore, in future studies with the sensory evaluation of vegetables, the consumers' background variables and different consumer segments should be identified.

Cultivation conditions affecting the sensory properties of vegetables

Different cultivars of vegetables may differ by sensory quality, and plant breeding may be used to improve the desired quality factors. For example, different genotypes of lettuce were shown to differ between the ratios of bitter and sweet compounds and further liking ratings (Chadwick et al. 2016). Additionally, the sensory attributes of seven salad rocket accessions were observed to differ according to the evaluations by the trained panel (Bell et al. 2017). Both consumers and chefs evaluated the sensory characteristics of nine cherry tomato accessions, and the results may help producers in the selection of the most promising cultivars (Rocha et al. 2013). For carrots, genetic factors have been found to have the highest impact on quality variables, followed by climate-related factors, while the cultivation method had less impact (Seljåsen et al. 2013).

Soil type and, presently, soilless production systems, have impacts on sensory parameters. It was reported that the sensory quality and consumer preferences of swede appeared to be affected by the variety, soil type and level of nitrogen fertilization (Thomsen et al. 2018). Soilless lettuce cultivation has been found to affect visual quality (Selma et al. 2012). In greenhouse production, the composition of nutrient solutions used in irrigation have effects on the sensory characteristics of greenhouse tomatoes (Cliff et al. 2012). Gruda (2005) has reviewed the impact of environmental factors on the quality of greenhouse vegetables. Potential impacts of climate change on vegetable production and sensory quality deserves further research (Bisbis, Gruda, and Blanke 2018).

Growth temperature and high latitude light conditions have been shown to affect the sensory quality of swede roots. For example, low growth temperature was associated with acidic odor, sweet taste, crispiness and juiciness (Johansen et al. 2017; Mølmann et al. 2018). Temperature and light conditions related to latitude and season have also been shown to affect the sensory quality of broccoli (Johansen et al. 2016). Furthermore, seasonal variation in color and texture of packaged wild rocket have been reported (Edelenbos, Lokke, and Seefeldt 2017). In greenhouse production, ultraviolet radiation had effects on tomato flavor (Dzakovich, Ferruzzi, and Mitchell 2016). In the case of tomatoes, early harvesting at an intermediate ripening state combined with refrigeration affected the sensory profile negatively compared with fully ripened tomatoes (Raffo et al. 2018).

Presently, many consumers value naturalness and environmental protection, and they are important drivers for buying organic foods (Janssen 2018). However, in blind testing, significant sensory quality differences have usually not been detected between organically or conventionally grown vegetables (Zhao et al. 2007). Bach, Kidmose, et al. (2015) found no differences in sensory quality between organic and conventional carrots. Various sensory attributes evaluated in nine organic or conventional fruits and vegetables also did not differ significantly (Tobin, Moane, and Larkin 2013). Recent study with university students found that participants did not perceive differences between organic and conventional leafy green vegetables in blind testing, while higher scores were given to those products labeled as organic during the informed test (Da Cunha et al. 2019).

The impact of growing conditions on all sensory aspects of different vegetables is a vast topic and comparisons between studies are challenging. Growing conditions vary a lot between greenhouse or arable land production, and furthermore, soil type and cultivation techniques differ. Additionally, climate conditions vary between latitudes, years and seasons. However, growing conditions can have a significant effect on the sensory properties of vegetables. Thus, in studies concerning cultivation conditions and methods, the importance of including the sensory evaluation of vegetables and consumer perspective should be highlighted.

Effects of storage and processing methods on the sensory properties of vegetables

Postharvest factors affecting quality reduction include retail temperature, storage atmosphere and heating procedures in processing (Seljåsen et al. 2013). Kyriacou and Rouphael (2018) emphasized in their review article the importance of both pre- and postharvest factors for the quality of fresh vegetables. Mahajan et al. (2017) have reviewed the quality and safety aspects of fresh vegetables, and especially the effects of postharvest treatments on the quality attributes, including sensory parameters.

After harvest, refrigeration of vegetables is needed in wholesale, retail trade and home. The commercial cold chain is usually well controlled, but the temperature in domestic refrigerators may vary considerably. The increase in storage temperature may affect sensory quality and has been observed to increase consumer rejection of fresh-cut iceberg salad (Manzocco et al. 2017). Reviews focusing on single vegetable groups have been published, for interested readers e.g. the impact of processing and storage on the sensory properties of Brassica vegetables (Martínez et al. 2020).

Vegetable freshness is an important quality attribute, but the perception of freshness is complex and consumer opinions on vegetable freshness may depend on vegetable type and situational context (Saba et al. 2018). It has been shown that consumers recognize differences between freshly cut and ready-to-eat lettuce in food service environments (Kumpulainen et al. 2016). In the case of consumer evaluation of ready-to-eat mixed salad leaves, both liking and freshness were related to appearance attributes (Dinnella et al. 2014).

Markets of fresh-cut fruits and vegetables have been increasing in Europe (Baselice et al. 2017). Critical quality factors of fresh-cut products for consumer acceptance and sensory evaluation aspects have been reviewed by Barrett, Beaulieu, and Shewfelt (2010). New options for self-life extension of fresh-cut fruits and vegetables have been tested and include modified atmosphere packaging and edible coatings (Ghidelli and Perez-Gago 2018). Regarding the modified atmosphere packaging of precooked vegetables, the study carried out with different storage periods observed small sensory and physicochemical changes (Barbosa et al. 2016).

Freezing is commonly used for the longer preservation of vegetables, and sensory attributes may be susceptible to changes during freezing and defrosting. Industrial blanching and freezing processes may have effects on sensory quality, such as color and texture, but the changes also differ among vegetables (Mazzeo et al. 2015; Paciulli et al. 2015). The physicochemical parameters, such as starch content and hardness, were related to the sensory quality of frozen green peas (Nleya, Minnaar, and de Kock 2014). Defrosting methods also affected the sensory properties and consumer acceptance of frozen broccoli (Villarreal-Garcia et al. 2015).

Selection of the optimal cooking method is critical for the sensory properties of vegetables. Three different cooking methods (boiling, steaming and frying) of selected vegetables were evaluated by Miglio et al. (2008), and they reported that steamed vegetables had better texture than boiled ones. Medium-firm broccoli, both steamed and boiled, was the most liked by consumers (Bongoni et al. 2014). Domestic processing of broccoli and carrots in Dutch households was investigated by online questionnaires, and the results indicated that approximately 70% of the consumers boiled while 8–9% steamed vegetables (Bongoni et al. 2015). Different varieties of vegetables may be more suitable for different preparation methods; for example, different beetroot varieties are suitable for boiling or pan frying (Bach, Mikkelsen, et al. 2015).

New cooking methods, such as sous-vide and cook-vide, have also been applied to vegetables (Iborra-Bernad, García-Segovia, and Martínez-Monzó 2015). Sensory testing of green bean pods showed that sous-vide treatment was preferred by consumers compared with cook-vide and traditional cooking (Iborra-Bernad et al. 2013). Low-pressure cooking was shown to enhance the flavor profile of vegetable broth (Mougin et al. 2015).

In conclusion, selecting the most appropriate storage and cooking conditions may have significant effects on the sensory properties of vegetables. Processing methods in industrial scale and at home may differ and are difficult to compare. Considering restaurants and catering services, the above-mentioned factors are crucial to maintain consumer acceptance and satisfaction with vegetable servings. More research is needed on the relationships between cooking methods and changes in sensory properties to find optimal cooking solutions of vegetables for different consumer groups.

Flavor modification of vegetables

One solution to improve the palatability and increase the consumption of vegetables could be flavor modification. Masking bitterness has been studied most, especially among bitter taste-sensitive consumers. According to studies of taste interactions in aqueous solutions, salts and sweeteners have been shown to suppress bitterness (Wilkie and Capaldi Phillips 2014). Table 1 presents studies reporting the effect of flavoring of vegetables on sensory evaluation results with adult subjects. These are examples how vegetable samples have been studied among specific study populations, but

Table 1. Sensory evaluation of seasoned vegetables by adult consumers.

Reference	n, gender, age (M = male, F = female)	Vegetables	Flavoring	Result
Bakke et al. 2018	2 experiments: *n* = 84 (35M, 49F) mean age 35 years *n* = 99 (30M, 69F) mean age 43 years	broccoli, spinach, kale	sugar, salt	sugar and salt reduced bitterness, sugar added to vegetable purees increased hedonic ratings
Beck et al. 2014	*n* = 19 total *n* = 8–11/ panel 26–56 years	white cabbage juice	sucrose	sucrose masked bitter taste
Feng et al. 2018	*n* = 749 total (divided to 4 sessions), 74% F 70% 18–25 years	broccoli, cauliflower, carrot, green bean	spice and herb seasonings	seasoned vegetables more preferred
Ghawi et al. 2014	*n* = 72 consumer test 18-65 years	broccoli	mustard seed	1/3 consumers liked, but majority disliked mustard-derived sensory attributes
Sharafi, Hayes, and Duffy 2013	*n* = 37 (16M, 21F) 18–32 years	brussels sprouts, kale, asparagus	NaCl, sodium acetate, aspartame	aspartame most effective bitter blocker for PROP tasters
Van Stokkom et al. 2018	*n* = 100 (16M, 84F) mean age 33 years	cucumber, green capsicum	sucrose, citric acid, caffeine, MSG, NaCl, sunflower oil	only enhancement of sweetness increased acceptance
Wilkie, Capaldi Phillips, and Wadhera 2013	3 experiments: *n* = 102 (61M, 41F) *n* = 69 (43M, 26F) *n* = 199 (109M, 98F) university students	broccoli, cauliflower, brussels sprouts	sucrose, saccharin, aspartame, sucralose	sucrose and sweeteners suppressed the bitterness of vegetables significantly
Wilkie, Capaldi Phillips, and Wadhera 2014	*n* = 66 (40M, 26F) mean age 19.5 years	brussels sprouts, cauliflower	NaCl	decreased bitterness ratings, increased hedonic ratings

practices related to flavoring of vegetables deserve further studies with various consumer segments.

Traditionally, salt has been used to mask bitter taste and improve the palatability of cooked vegetables (see Table 1, Bakke et al. 2018; Sharafi, Hayes, and Duffy 2013; Wilkie, Capaldi Phillips, and Wadhera 2014). Sucrose and sweeteners have also been tested for reducing bitterness (Table 1, Bakke et al. 2018; Beck et al. 2014; Sharafi, Hayes, and Duffy 2013; Wilkie, Capaldi Phillips, and Wadhera 2013). Recently, Van Stokkom et al. (2018) studied taste enhancement of vegetable purees by all five taste modalities and fat, and they found that only sweetness significantly increased acceptance. Other options such as herbs and spices have also been tested (Feng et al. 2018). Individual preferences in seasonings may be considerable among consumers, as in the case of mustard seeds (Ghawi et al. 2014). In addition to adults, herbs and spices were found to improve vegetable liking among high-school students aged 14–18 years (Fritts et al. 2018). Furthermore, elderly consumer groups may have different preferences for seasoning of vegetables.

In addition to sensory laboratories, seasonings have also been tested in real-life conditions. In a public café at a university campus, customers were more likely to select seasoned vegetables than unseasoned vegetables (Manero et al. 2017). A recent study at a university café showed that customers purchased seasoned green beans, broccoli and cauliflower more frequently than steamed versions, while there was no difference in carrots (Luu et al. 2020). In fact, it has been observed that offering a dip increased broccoli intake among children (Fisher et al. 2012). Balsamic vinegar is often added to green salad and may provide various sensory attributes (Torri et al. 2017). Low-fat pork gravy was found to significantly reduce the vegetables' own flavor (cauliflower, broccoli, and potato), but bitter and sour tastes increased (Meinert et al. 2011). In practice, at home or with catering services various herbs and salad dressings might be good alternatives to season vegetables instead of salt.

Many studies mentioned above have rather small population samples and some have focused on the consumer groups with different sensitivity to bitter taste, such as PROP taster groups. It is also difficult to make final conclusions based on the sensory properties and preferences of single vegetable samples reported in one study, and thus the actual food behavior and vegetable consumption patterns should be studied. Therefore, more studies with larger consumer groups and segments are clearly warranted. International comparisons are difficult, because different food cultures have different ways of using and seasoning vegetables, and therefore local culinary practices related to individual preferences should be investigated. However, different flavoring options deserve further studies as a strategy for improving the palatability of vegetables.

Vegetables as part of meals and food products

Because vegetables usually accompany meals, the whole composition of the meal may affect the perceived quality. In lunch food choices, the diversity of colors provided with vegetable components were preferred by consumers (Paakki, Aaltojärvi, et al. 2019). In mixed salads, the colorfulness and color contrasts impacted visual attractiveness (Paakki, Sandell, et al. 2019). Combinations of vegetables may be perceived more acceptable than individual vegetables (Van Stokkom et al. 2019). The preferences for visually presented component dishes, including vegetables as a root mix or wok mix, have been found to differ by consumer segments (Reisfelt et al. 2009).

Serving a variety of vegetables has been shown to increase vegetable intake at the meal (Meengs, Roe, and Rolls 2012) and providing choice to increase vegetable liking and intake (Parizel et al. 2017). König and Renner (2018) reported that increased variety in meal color was related to an increased intake of vegetables. On the other hand, color variety was found to increase fruit and vegetable intake and purchase intentions only in some subsets of adults (Vadiveloo et al. 2019). Style of plating may also affect ratings and willingness to pay for the dish—e.g. when vegetable salad was arranged in an artistically inspired manner (Michel et al. 2015).

Modification of recipes to increase vegetable content in meals is also possible. Pureed vegetables incorporated into entrées were shown to increase vegetable intake and decrease energy intake (Blatt, Roe, and Rolls 2011). Spencer and Guinard (2018) tested different flavor modalities (taste, aroma, trigeminal, and their combination) to increase the sensory appeal of dishes with partially replacing meat with vegetables. They showed that trigeminal (spices: e.g. ginger, chili, cayenne pepper) and trimodal strategies worked best, but individual preferences varied regarding spiciness and saltiness. In mixed dishes, as a partial replacement for meat, a mixture of legumes and vegetables and trigeminal boost with spices was found to maintain flavor complexity and consumer acceptability (Spencer, Cienfuegos, and Guinard 2018). Studies in real-life restaurant settings in the Netherlands demonstrated that adapting portion sizes of meat and vegetables reduced meat and increased vegetable consumption (Reinders et al. 2017; Reinders et al. 2020). Consumer satisfaction was also shown to increase when vegetables were prepared and presented in a more attractive way (Reinders et al. 2020).

Enriching new products with vegetables may be used to increase vegetable intake. In consumer evaluation, no significant differences were observed in the overall liking among three different vegetable-enriched breads compared with control bread, except for red beetroot bread (Hobbs et al. 2014). Vegetable ingredients may also be incorporated into other products, for example pasta (Oliviero and Fogliano 2016). Fruit- and vegetable-based snacks have been evaluated among adolescents, and gender and neophobia were shown to be associated with affective responses (Mielby et al. 2012). Ready-to-eat dried vegetable chips (Konopacka et al. 2017) and vegetable-based smoothies (Gonzalez-Tejedor et al. 2017) are also on the market currently. Considering these new types of vegetable products, the evaluation of sensory properties is essential to ensure consumer acceptance.

External sensory cues affecting vegetable perception and choice

Previous chapters in the present review have described the internal quality factors and processing practices related to the sensory properties of vegetables. This chapter focuses on external factors—for example, color, odor and multisensory modification of the environment—in relation to vegetable perception. These external modifications might offer new innovative options to promote vegetable consumption.

Promoting healthy food choices in food marketing strategies or nutrition interventions have been a focus in research recently. Nudging may be considered a term including methods of changing behavior by modifying cues in the physical and/or social context, for example product placement or environmental cues (Vecchio and Cavallo 2019). Different nudging techniques in the promotion of fruit and vegetable choice have been reviewed by Broers et al. (2017). Spence (2020) has recently published a comprehensive review on different nudging options related to leafy greens.

Colorful vegetables as such are visually appealing, but the colored background or color of the lighting may also affect attractiveness. Five different vegetables were presented on four different background colors, and the results showed that the colored backgrounds affected the perceived attractiveness of vegetables, and the optimal background color differed among vegetables (Schifferstein, Howell, and Pont 2017). Howell and Schifferstein (2019) studied the attractiveness of fresh vegetables (tomato, carrot, yellow bell pepper, eggplant, mushroom) on five different backgrounds with neutral gray colors varying in degree of blackness. They concluded that consumers generally find vegetables more attractive on dark backgrounds. Furthermore, package color was shown to affect visual appeal, perceived quality and purchase intention of fresh produce (Bix, Seo, and Sundar 2013).

Hasenbeck et al. (2014) used photographic slides of bell peppers under five different colored LED lighting as visual stimuli. They reported that lighting color and illuminance level influenced consumers' liking of appearance and willingness to consume bell peppers. Furthermore, sliced red bell peppers were presented under five different colors of light, and it was found that participants were more willing to eat bell peppers and liked the appearance under white or yellow light (Yang, Cho, and Seo 2016). These findings on background colors and lighting could be applied and studied more—for example, in grocery stores or food services—to improve the attractiveness of vegetable selection.

Olfactory cues have also been tested to prime food choice. Gaillet et al. (2013) showed that participants in the melon-scent condition were more likely to choose starters with vegetables from a list presented as a restaurant menu (menu task), than participants in the nonodorized control condition. On the other hand, cucumber odor in the test room did not affect choices in a real-life lunch buffet (Mors et al. 2018). Priming with creating a leafy environment with green plants and odor of herbs or increasing the visual variety by serving salad vegetables as separate components, were found to decrease the intake of the meat-based meal component in a self-service buffet setting, while the intake of vegetables did not differ significantly (Friis et al. 2017).

Sensory testing has been traditionally performed under standard sensory laboratory conditions, which may differ significantly from real-life eating situations. Currently, various multisensory testing facilities allow the creation of

virtual testing environments and investigating the effect of various external factors simultaneously on the perception of food (Bangcuyo et al. 2015). In an Italian study (Sinesio et al. 2018), the immersive environment setting in a multisensory room included large wall screens presenting a countryside landscape, audio and olfactory stimuli (natural herbs) and furniture for modeling a holiday farm dining room. It was found that the liking scores of salad tomato and wild rocket samples were higher when consumer evaluations were performed in the immersive environment setting than in the traditional sensory laboratory setting (Sinesio et al. 2018).

Further relating to real-life, consumer perceptions of restaurant environments and real food intake are important to study. Bschaden et al. (2020) studied the impact of lightning and table linen as ambient factors in the intake and taste perception of tomato soup. In the dimmed light condition with tablecloth, the participants ate the largest amount and rated the soup the highest in terms of overall quality. Kontukoski et al. (2016) asked participants to match interior color, background music and desired emotional states for either a salad or steak restaurant. Lime color and jazz, pop and soul music were chosen most often for the salad group. Creating multisensory eating environments to promote vegetable choice and consumption deserves further study.

Summary of options to promote vegetable intake among adults

In general, better understanding about individual food choice motives and different consumption contexts by consumer segments is important for the development of targeted interventions (Verain et al. 2020). Considering the individual variation in sensory perception, different consumer groups may need tailored interventions focusing on taste masking or modification. Thus, new approaches presented in the previous chapters could be applied to increase vegetable consumption among adults. To sum up, the basis is to ensure the high internal quality of vegetables with the selection of appropriate cultivars and cultivation methods. Further, proper storage and processing conditions are important in maintaining the sensory properties. Cooking practices with seasonings and modification of recipes or meal composition may increase the palatability of vegetable dishes. Finally, external sensory cues related to choice or eating situation may improve the consumer experience.

Promoting vegetable and fruit consumption among the adult population is a continuous challenge. Practical and comprehensible information campaigns are still needed—for example, the ‘five-a-day’ message may not be clear for consumers (Rooney et al. 2017). Vegetables are often promoted with health-related information, but even though consumers were aware of the health benefits, the sensory perception tended to predict liking and intentions to consume Brassica vegetables (Cox et al. 2012). Consumers are often conservative and prefer conventional and familiar products (Cox and Poelman 2015). The adoption of new habits related to vegetables may be a slow process. Because the consumption of ready-to-eat meals and eating outside the home have been increasing, food industry and food services play an important role in providing tasty vegetable dishes for their customers.

Repeated exposure and sensory-based activities have been shown to promote vegetable liking and intake among children (Dazeley, Houston-Price, and Hill 2012; Hoppu et al. 2015). These methods could also be applied for adults; for example, vegetable tasting can be included in nutrition education courses focusing on vegetables (Brown et al. 2011). Moreover, community setting intervention for older consumers with repeated exposure to fruit via fruit-tasting sessions once per week for 5 weeks significantly improved fruit intake in low consumers of fruit (Appleton 2013). In-store marketing intervention combining shelf labeling and marketing strategies (taste testing, signage, and prime placement) was observed to increase the purchase of fruit and vegetables (Gamburzew et al. 2016). In general, cooking skills have been positively associated with vegetable consumption (Hartmann, Dohle, and Siegrist 2013; McGowan et al. 2017).

In conclusion, individual differences in the sensory perception of vegetables may be large. The sensory aspects may be modified with different preparation methods, seasoning and external factors during meal. In addition to their healthy nutrient content, vegetables provide esthetic and culinary experiences that may promote well-being. New types of interventions for adults focusing on taste and other sensory qualities of vegetables, increasing the variety of vegetables used and combined with cooking skills might be useful. Creating delicious vegetable food products and pleasant dining environments could increase vegetable consumption, thus promoting environmentally sustainable food choices and public health.

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