

# Flavour preferences in youth versus adults: a review

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## ABSTRACT

**Objective** To understand the available evidence of how children and adults differ in their preferences for flavours that may be used in tobacco products.

**Data sources** A total of 474 articles published between 1931 and August 2015 were retrieved through searches conducted in PubMed, EMBASE, Web of Science and PsycINFO.

**Study selection and extraction** A 2-phase relevancy review process resulted in the identification of 59 articles and information was extracted by 2 independent reviewers.

**Data synthesis** Findings were grouped by taste and smell preferences, which are important components of overall flavour. For taste, evidence is summarised in the following categories: sweet, salty, sour, bitter, umami and fat; within each of them, findings are organised by age categories. For smell, evidence is summarised as follows: fruit/herbal/spices, tobacco and coffee and other odours. Major findings from this search indicated that sweet preference in children and adolescents was higher than in adults. Examples of preferred food-related tastes and odours for young people included cherry, candy, strawberry, orange, apple and cinnamon. Currently, all these are used to flavour cigars, cartridges for electronic cigarettes, hookah (waterpipe) and smokeless tobacco products.

**Conclusions** Infants and children exhibited elevated sweet and salty preference relative to adults. Age-related changes in bitter, sour, umami and fat taste were not clear and more research would be useful. 'Sweet' food odours were highly preferred by children. Tobacco products in flavours preferred by young people may impact tobacco use and initiation, while flavours preferred by adults may impact product switching or dual use.

## INTRODUCTION

Although cigarettes are no longer allowed to be marketed in the USA with characterising flavours other than tobacco or menthol, other tobacco products such as cigars, hookah (waterpipe) and e-cigarette liquids are available in a variety of flavours.<sup>1</sup> The WHO has raised concerns on how flavoured products could encourage tobacco use by masking the smoke flavour and consequently enhancing sensory rewards.<sup>2</sup> In addition to the menthol cigarette market, the tobacco industry is known to have periodically experimented with flavoured cigarettes (beyond menthol), generally targeting younger smokers and women.<sup>3</sup> Tobacco industry documents reveal that younger smokers are more open to unique flavours.<sup>3</sup>

Studies show younger adults and adolescents prefer flavoured tobacco products.<sup>4 5</sup> Estimates derived from the National Adult Tobacco Survey

(2009–2010) showed a higher percentage of adults aged 18–24 smoke flavoured cigars than those aged 25–44 and the National Youth Tobacco Use Survey (2014) showed the majority of current hookah, cigars, e-cigarettes and smokeless product users used flavoured tobacco products.<sup>4 5</sup> Furthermore, the longitudinal Population Assessment of Tobacco and Health Study found a majority of youth who self-reported ever experimenting with tobacco started with a flavoured product, and most current youth tobacco users reported use of flavoured products.<sup>6</sup> However, little is known about how age-related flavour preferences influence the choice to use flavoured tobacco products. This review aims to identify how children, adolescents and adults of different ages differ in their preferences for flavours that are or could be used in tobacco products.

Studies of flavour perception can generally be divided into either sensitivity to chemical stimuli or the hedonic dimension of flavour. The former includes thresholds, intensity judgements and sensory adaptation. Ratings of pleasantness or preferences are descriptors of hedonic response.<sup>7</sup> Here, however, flavour is defined as the perceptual attribute of foods and beverages resulting from integration of multiple primary sensory inputs from the gustatory, olfactory and trigeminal systems.<sup>7</sup> The interactions among these anatomically distinct senses are essential in to fully understand flavour perception, but will not be addressed here.<sup>8</sup> Instead, the focus of this paper is the independent gustatory and olfactory components of flavour, as they are highly salient and the most often investigated.

Taste and smell play key roles in the acceptance or rejection of food. Taste refers to the sensation resulting from chemicals stimulating taste receptors in the tongue and oropharynx.<sup>9</sup> Smell contributes to flavour via the aromas of substances, which then are driven into the nasal cavity where the olfactory receptors reside. This component of smell is called retronasal olfaction.<sup>7</sup> Other senses of touch, temperature and irritation elicited by substances in the oral and nasal cavities activate the trigeminal system,<sup>7</sup> whose nerves mediate much of the chemesthetic flavour sensations.<sup>8</sup> Some well-known examples of chemesthetic sensations are the stinging or tingling of carbonation in the nose and mouth and tear-induction by onions.<sup>8</sup> Despite the relevance of smell to the taste of tobacco products, particularly smoke components since they directly interact with the surface of the oral and nasal cavities, the particular components of smell are not included in this review because there is little information on age-related changes in these components of flavour.



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This review sought to identify differences in flavour preferences and how flavour preferences vary by age (eg, youth, adolescent, adult). Since there are no reports of differences in flavour preferences of tobacco products by age, the goal of the review was to identify which food, beverage and candy flavour preferences change with age and might therefore translate to likely age-related flavour preferences of tobacco products.

## MATERIALS AND METHODS

The search of PubMed, EMBASE, Web of Science and PsycINFO used search terms related to flavour, product, preference and population was performed in August 2015 (table 1). The results of the search and the process for determining relevancy are presented in figure 1.

Articles (n=59) were included if they (1) were peer-reviewed, (2) contained primary research or new analyses of previously conducted studies and (3) had outcomes directly related to the research questions. Articles were excluded if they (1) were not

in English, (2) in a book or periodical, (3) were a commentary or editorial, (4) focused on perceptions of packaging or marketing or (5) dealt exclusively with the physiological development of taste or smell.

This review is organised according to the five generally accepted taste quality categories (sweet, salty, sour, bitter and umami) plus a sixth category, fat, which may or may not be mediated in part by taste receptors.<sup>10</sup> Unlike the case for taste, there is no agreement on a classification scheme for smell stimuli.<sup>7</sup> Consequently, studies describing effects of age on smell ratings were divided into three categories: fruit, herbal and spice odours; tobacco and coffee odours and other odours. Within each category of taste and smell, three broad age groups were defined: children, adolescents and adults. However, it is critical to note that due to lack of standardisation, there was no consistent age cut-off for each group. Specifically, in the first group, a distinction was made between school-aged children and children of younger ages; in the second group, depending on availability of information, results for younger adolescents were separated from those of older adolescents; and among adults, if possible, results for older adults ( $\geq 65$  years) were presented separately. Whenever possible, specific results for young adults (18–25 years) were described. Age differences and other summary results measures from each study are provided in online supplementary tables S1–S3. Additional information about the studies (eg, sample size, participant ages, study design, study location, preference-related outcomes) are available in online supplementary table S4.

## RESULTS

### Findings

Taste preferences (see summary of findings in online supplementary tables S1 and S2).

#### Sweet taste preference in children

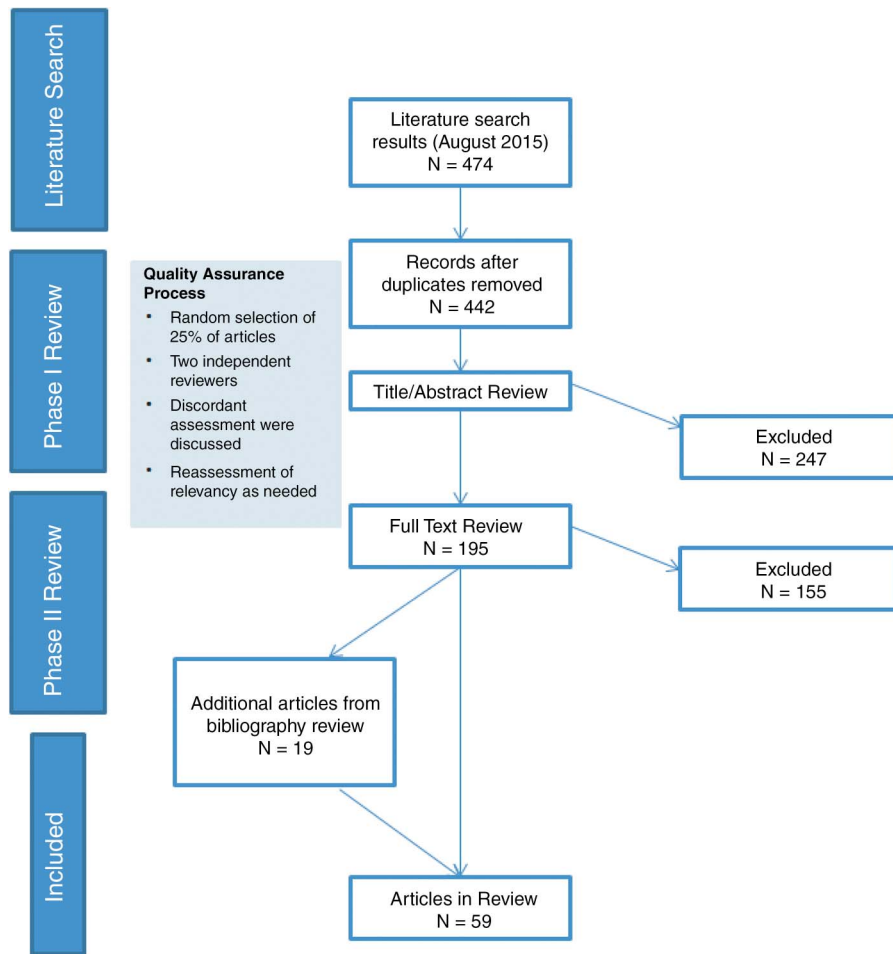
Seven papers described sweet taste preference among infants and children. Four papers compared children with other age groups. Among infants, sweet taste was preferred over water during the first year.<sup>11</sup> Engen<sup>12</sup> found young children rated sweet as a preferred flavour. Older children also preferred sweet taste. Two studies found a higher proportion of older children preferred sweeter apple juice than did younger children.<sup>13 14</sup> However, these results might have been due to the use of a single concentration of sweetener to evaluate sweet preference.<sup>13 14</sup> In a questionnaire study of schoolchildren, liking for fruits and fatty/sugary foods was highest around 8–11 years.<sup>15</sup> Papers in this review also showed that early experiences may influence later preferences.<sup>16 17</sup> Longitudinal studies compared preferences for sucrose solution and water in infants at birth, again at 6 months<sup>16 17</sup> and again at 2 years.<sup>16 17</sup> Children fed sweetened water at study onset ingested more sucrose solution than those not previously fed sweetened water.<sup>16 17</sup> However, this early experience had no effect on the degree to which they liked sweetened Kool Aid at 2 years. The authors suggested that the learning was not to like more sweetness itself but to like sweetness in certain food contexts.<sup>16 17</sup>

Sweet taste preference decreases with age. Preference for concentrations of sugar in water and lemonade was children > adolescents > young adults.<sup>18</sup> Similarly, compared with young adults, younger children preferred higher concentrations of sugar in orangeade.<sup>19</sup> Also, compared with their mothers, children preferred a more intense concentration of sucrose in water and pudding.<sup>20 21</sup>

**Table 1** Search terms

Flavour	Product	Preference	Population
Taste	Food and beverages	Preference	Adult
Flavouring agents	Food additives	Choice	Child
Sweetening agents	Tobacco products	Difference	Humans
Flavour/flavour	Food	Food preferences	Adolescent
Menthol	Beverages	Drinking behaviour	Youth
Sweet	Confection	Consumer behaviour	Young adult
Sour	Chewing gum	Attitude	Teenagers
Bitter	Candy	Choice behaviour	Tween
Salt	Alcohol	Food habits	Juvenile
Umami	Coffee	Variation	Middle aged
Fat	e-Cigarettes	Liking	Age factors
Smell	Soda/soft drink	Favourite	
Chemesthesis	Chewing tobacco	Pleasant	
Somatosensory	Snuff	Unpleasant	
Odour	Dissolvable	Hedonics	
Colour	Cigarettes	Genes	
Sodium chloride, dietary	Cigars	Learning	
Sodium glutamate	Hookah/waterpipe	Perception	
Dietary fats	Ice cream	Enjoyment	
Olfactory perception	Snacks		
MSG	Yogurt		
Fruit	Milkshakes/smoothies		
Mint	Medicine		
	Dessert		
	Dairy products		
	Fast foods		
	Alcoholic beverages		
	Carbonated beverages		
	Energy drinks		
	Tobacco, smokeless		
	Electronic cigarettes		
	Smoking		
	Prescription drugs		
	Pharmaceutical solutions		

**Figure 1** Search and the process for determining article relevancy.



Taken together, sweet taste is strongly preferred in early years of life; children prefer higher concentrations of sugar in water and food than do older individuals.

#### Sweet taste and preference in adolescents

Two papers described sweet taste preference among adolescents. Analysis of a questionnaire of food habits and preferences in a cross-sectional sample of French adolescents and young adults found sweet was the most preferred taste quality in each age group. Sweet was always preferred to bitter and sour. In later adolescence, liking for bitter and sour increased but remained lower than sweet ratings.<sup>22</sup> Among 18–20 years, no differences were observed in self-reported preferences for sweet, salt and sour.<sup>22</sup> A longitudinal study found that adolescents selected a higher level of sucrose as more preferred compared with their ratings as adults.<sup>23</sup>

Six papers compared the taste preferences of adolescents with adults. Taste preferences of sucrose, lactose and sodium chloride in children and adults significantly differed by age, with greater preference for sweetness (lactose and sucrose) in the younger group. Also, African-American children selected significantly sweeter concentrations compared with white children.<sup>24</sup> Another paper reported Hispanic adolescents preferred higher intensities of cocoa flavour and aroma in chocolate milk compared with Hispanic and Caucasian adults; there were no Caucasian adolescents. This finding was attributed to adolescents' preference for higher sweetness intensity.<sup>25</sup> Two additional studies reported higher concentrations of sucrose were preferred by children compared with adults. Among men, preference for sweet stimuli decreased with age; the preferred sugar (sucrose) level in sugar/

fat mixtures among adolescents <16 was over twice as high as preferred sweetness levels of older adolescents and adults.<sup>26</sup> Similarly, adults preferred lower concentrations of sucrose in solutions and cereals than children and adolescents.<sup>24</sup> When sucrose was added to a food and beverage over several days, children, but not young adults, showed increased preference for that food or beverage.<sup>27</sup> Finally, compared with young adults, pre-adolescents and adolescents found sweetened alcoholic and milk-based beverages more acceptable.<sup>28</sup>

Taken together, sweet taste was preferred in all ages of children over other tastes and preference for sugar was higher in younger versus older adolescents, and adults.

#### Sweet taste and preference in adults

Nine papers described sweet taste preference among adults. When taste preferences were examined in young adults, intermediate-age adults, and adults aged 65+ years, older adults found sugar more pleasant at higher concentrations compared with young adults and intermediate-age adults.<sup>29</sup> French adults' liking scores for sweet significantly decreased with age,<sup>30</sup> although sweet was still a preferred taste. Differences in degree of habituation (decreased oral responsiveness following repeated exposure) for very sweet foods have been reported across four groups of adults. Following repeated exposure to very sweet food, white participants displayed habituation; African-Americans did not.<sup>31</sup>

Preference for some sweet foods and drinks was inversely related to participant age (from 14 to 65 years). Compared with older participants, younger participants reported greater preference for sweets (ie, candy, sodas, carrot and orange juice).<sup>32</sup>

Among adult twins, liking scores for the taste of sucrose (sweet) was significantly associated with age as a negative correlation.<sup>33</sup> Although there was decreased preference for higher concentrations of sweeteners from childhood through adulthood, there was evidence for a change in direction among older adults.<sup>29 34</sup> A study that investigated sensory perception and pleasantness of orange beverages found that, compared with younger participants, older participants preferred sweeter beverages and more sour beverages.<sup>35</sup> However, another study failed to find age-related differences in preference for sucrose concentration.<sup>36</sup>

#### Salt taste preference across age ranges

Eleven papers described salt taste preference among young participants, five of which had adult comparators. Acceptance for salty taste increased in infants over the first year of life.<sup>11</sup> Young children preferred higher salt concentrations in soups and food<sup>17 37</sup> and preferred higher salt concentrations compared with parental preference.<sup>37</sup> Complementary results were found in two additional studies.<sup>20 38</sup> A study on taste preferences among European children reported an increase in the odds for salt preference with age.<sup>14</sup> As noted earlier, salt and sugar were the most preferred tastes among adolescents. Among young adults, no differences were observed in preferences for salt, sweet and sour.<sup>22</sup> Children and young adolescents preferred greater saltiness than adults. Some racial/ethnic differences were noted: the youngest group of African-Americans selected significantly saltier concentrations than other racial groups.<sup>39</sup>

Among American young adults and adults, sodium chloride (salty) was rated significantly less pleasant than sucrose (sweet). Older adults found salt more pleasant at higher concentrations than younger adults.<sup>29</sup> Older participants also showed higher preference for salt concentrations in foods than younger adults.<sup>40</sup> Among French adults, salt liking slightly increased with age in men, but not in women.<sup>30</sup>

In general, young children, adolescents and older adults preferred higher concentrations of sodium chloride compared with intermediate-age groups.

#### Sour taste preference in youth and adults

Seven papers described sour taste preference. Moderate concentrations of sour and bitter taste stimuli were the least accepted by infants compared with sweet and salty stimuli at each age tested.<sup>11</sup> Although not preferred compared with sweet and salty, Liem *et al* found that young children preferred higher levels of sour taste in gelatine compared with adults. Interestingly, children preferring sour tastes most were significantly less food neophobic.<sup>41</sup> Adding sugar reduced children's initial dislike for the taste of grapefruit juice, even when sugar was later removed from the juice.<sup>42</sup> Individuals aged 14–20 years said that they liked sour tasting flavours more than younger (10–13 years) children; by 18–20 years, preferences for sweet over sour were no longer present.<sup>22</sup>

Adults rated sour as significantly less pleasant than sweet. Older adults found sour significantly less pleasant than salty, whereas young and intermediate-age adults showed the opposite preference. Concerns over indigestion of acidic (sour) substances may explain, in part, why older adults found sour taste less pleasant than the other flavours.<sup>29</sup> However, children and older adults preferred more intense sour flavours compared with other age groups. Although during adolescence, there were decreased ratings of pleasantness of more intense sourness, this attenuated with age.<sup>35</sup> While not preferred over other types of

flavours, others have reported a similar preference for more intense sour flavour among older adults.<sup>43</sup>

In general, sour taste was less preferred than sweet and salty tastes, but there is evidence that young children preferred higher levels of sour compared with adults and that liking may increase in older adulthood. As with salt taste, the mechanisms underlying these age-related differences are unknown.

#### Bitter taste and preference in youth and adults

Eight papers described bitter taste preference. Bitter was not a preferred taste in the first decade of life. Bitter and sour tastes were the least accepted in a sample of infants and among children aged 4–6 years.<sup>11 12</sup> In a cross-sectional questionnaire study, adolescents and young adults reported bitter was their least preferred taste; however, the liking for bitter taste increased in the early adolescent years.<sup>22</sup>

Adults tested for their responses to bitter stimuli demonstrated an aversion that decreased with age.<sup>44</sup> Experience reduces aversion to bitter flavours.<sup>16 27</sup> Adding sugar to broccoli or cauliflower reduced adults' dislike of them and this effect remained when the vegetables were subsequently unsweetened.<sup>42</sup> Bitterness could also be chemically masked, resulting in reduced ratings of bitterness. Among children and their mothers, chemical masks significantly reduced bitterness ratings of solutions of urea and caffeine.<sup>45</sup> Generally, bitter was the least preferred taste, particularly among those younger than 13 years.

#### Umami taste and preference in youth and adults

Two papers mentioned developmental changes in umami taste. Infants' reactions to umami were neutral (compared with their preference for sweet and salty).<sup>11</sup> Among European children, umami taste preference was inversely correlated with age. These results, however, might have been influenced by the medium used for evaluating liking and by the stimuli chosen.<sup>14</sup>

#### Fat taste and preference in youth and adults

Three papers investigated fat preference. In a study that described fat and sweet preferences in children, the proportion of children aged 8–9 years who preferred a fatty cracker was lower compared with children 1–2 years younger.<sup>13</sup> Another study showed a decrease in adults' liking for sweet, fat-and-salt and fat-and-sweet with age.<sup>30</sup> However, Mennella *et al*<sup>21</sup> showed contrasting results; children preferred a lower concentration of fat in pudding compared with their mothers. A possible explanation is higher fat concentrations suppressed the perception of sweetness, thus puddings with a lower fat content tasted sweeter.<sup>21</sup>

Smell preferences (see summary of findings in online supplementary table S3).

#### Fruit/herbal/spice odours: preference across age ranges

Six papers referred to odours of specific fruit, herbs or spices and described preferences by age groups. The smells of spearmint and cloves elicited fewer positive ratings from children than from older adolescents and adults.<sup>46</sup> Most children liked strawberry, bubblegum, cola and chocolate odours, but less than half liked green tea odour.<sup>47</sup> Results from a longitudinal study of young children showed an age-related increase in the liking for 'food odours' (eg, anise, fruit). Interestingly, an increase in 'food odour' liking was significant only in children with higher language skills, a finding which the authors suggested may be a function of understanding and expression, rather than sensory preference.<sup>48</sup> In addition, a study on olfactory preferences

during puberty showed children and adolescents moderately liked chocolate odours, slightly liked spearmint odours and moderately disliked onion odours.<sup>49</sup> Age did not affect the liking and disliking for odours of chemically pure substances (eg, vanillin and geraniol) in children, adolescents and young adults.<sup>50</sup> Among older adolescents and adults, the most often eaten bagel was cinnamon raisin, which was significantly sweeter in aroma and flavour than other flavours tested.<sup>51</sup>

**Tobacco and coffee odours: preference in youth and adults**

Three studies referred to tobacco and/or coffee odours. Few young children liked cigarette odour and only slightly more liked the odour of coffee. Significantly, more children whose parents smoked preferred cigarette odour compared with those from non-smoking homes.<sup>47</sup> Coffee flavoured ice cream was the least preferred flavour among children.<sup>52</sup> In a study of children and adolescents, liking for coffee odours significantly increased with age. Coffee odour ratings changed from ‘dislike slightly’ among children to ‘like moderately’ among adolescents.<sup>49</sup>

**Other odours: preference in youth and adults**

Four studies referred to other odours. The odours of meat and chicken were disliked more by pre-pubertal children than by children aged 14 years, while peanut butter was liked more by children aged 14 years. This study also found children and adolescents agreed they ‘disliked moderately’ the odours of cheese and fish.<sup>49</sup>

In an experiment investigating age-related differences in sensitivity as well as preference or liking, ‘the average older adult requires twice the concentration necessary for a young person to exceed the threshold for menthol’.<sup>53</sup> For example, it took a 10-fold increase in menthol concentration to produce a fourfold increase in perceived intensity for young adults and a twofold increase in perceived intensity for older adults. These thresholds were accompanied by age-related differences in pleasantness ratings; however, it was unclear if this was due to the odour or the irritating properties of menthol, which occurs at higher concentrations.<sup>53</sup>

The liking or disliking of odours did not vary much by age. When presented with chemically pure odour stimuli (eg, camphor, phenol and menthol), there were no age-related differences in liking or disliking of the odours. The authors suggested this may be due to having achieved relative maturity of physiological mechanisms by the younger ages.<sup>50</sup> Moreover, similar overall preference patterns in adults and children were found in another study.<sup>46</sup>

**SUMMARY**

The literature reviewed here covers a span of over eight decades (1931–2015). Reviewing literature published over a long period poses challenges including differences in statistical methods and

heterogeneity in the style of reporting results. Additionally, there were not common categorisations of age groups. Also, while some papers defined specific odours or tastes, others used generic labels such as ‘food flavours’, which made attempts to draw conclusions difficult. Importantly, the strengths of the testing methods varied greatly among the papers. The value of self-reported questionnaire studies is useful, but direct sensory tests are more likely to provide unbiased data. But in devising sensory tests, many complications arise. For example, a single test with one concentration of a stimulus is not as powerful as a study using multiple concentrations. Also, the medium that a taste stimulus is tested in can have major impacts on results and conclusions. Concisely synthesising this literature is difficult.

Despite these difficulties, this review revealed that children preferred sweet over salty and sour tastes, were neutral towards or liked umami and did not like bitter ones.<sup>34 44 54</sup> Caloric intake needed when growing is one possible explanation for children’s preference for sweeter liquids and solids. Desor and Beauchamp<sup>23</sup> suggested that younger individuals have higher caloric needs, which is expressed as heightened preferences for sweeter foods, and individuals then ‘reduce their preferred level of sweet as they mature’. Also, Coldwell *et al*<sup>54</sup> concluded that ‘change in sugar preference from high to low during adolescence appears to be associated with the cessation of growth’. Another explanation may be that so-called ‘sweet’ aromas are not detected by sweet taste receptors; therefore, sweet odours may be labelled as sweet because of their prior associations with sweet tasting foods and beverages. This provides further support for the influence of previous experiences on flavour preference.

There was also evidence of racial/ethnic variations in preference for sweet and salty taste;<sup>25 31 39</sup> the relative influence of genetic, cultural and/or environmental variation is unknown. Children preferred fruit and candy odours to herbal odours.<sup>47 48</sup> Children generally did not like tobacco or coffee odours, although liking for coffee odour increased with children’s age<sup>47 49 52</sup> and parental smoking played a significant role in children’s preference for cigarette odour.<sup>47</sup> Since odour plays a critical role in flavour perception, the bitter taste of tobacco may be reduced if these children smoke a cigarette, making the cigarette more palatable.

Adults also preferred sweet more than salty.<sup>29 34 55</sup> Preference for sweet or salty tastes was generally reduced with advancing age until older adulthood was reached, when a preference for more intense flavours of sweet and salty emerged.<sup>19 20 24 26 27 29–35 37–40 46 47 51 54</sup> Unlike with sweet and salty, relatively little is known about developmental changes in liking for sour, bitter and umami tastes. One paper indicated young children showed a marked preference for sour tastes,<sup>19</sup> whereas other papers reported sour taste liking increased during adolescence and aversion decreased with age.<sup>22 27 35 43</sup> Young children disliked bitter tastes<sup>11 12</sup> and, as with sour taste, liking of bitter taste increased in early adolescence and aversion to this taste was attenuated with age.<sup>9 22 44</sup> Studies conflicted on whether children or adults preferred fat taste more.<sup>13 21 30</sup> The paucity of data prevented generalisations about age-related changes in umami or fat taste preferences.

Adults liked spearmint and clove odours more than children, although generally children and adults were very similar in their judgements of odour pleasantness.<sup>46</sup> Older adolescents and adults preferred blueberry and cinnamon raisin bagels, which were rated as sweeter in aroma and flavour,<sup>51</sup> suggesting even though adults’ preferences for sweet and fruit may be lower than children’s, the pattern of preference remains. Older adults preferred more intense sweet, salty and sour tastes. This reversal

**Table 2** Summary of overall group differences in flavour preferences

Flavour/taste	Group differences
Sweet	Children>adolescents>adults*
Salty	Children>adults*
Sour†	Adolescents>young children*
Bitter†	Adolescents>young children

\*Preference rises in older adulthood.  
†Based on very few studies.

in older adulthood may be due to a reduction in specific sweet, salty and sour taste sensitivities; a general reduction in taste sensitivity; or could reflect a desire to make up for the sensory loss of smell input, which is common in older individuals.<sup>29 53</sup> Overall group differences are listed in table 2.

Age-related changes may also reflect the role of experience; a significant mitigating factor in preference for certain tastes and food odours in children and adults. Experience alters preferences for sweet and salty tastes.<sup>16 17 27</sup> It also may reduce aversion and increase acceptance, as was found with sour and bitter tastes and tobacco odours.<sup>42 47</sup> Similarly, bitterness of urea and caffeine was suppressed with the addition of a chemical inhibitor, presumably because it inhibits bitterness at the receptor level.<sup>45</sup> Odours may be particularly susceptible to experience since odours are associated with certain foods.<sup>48</sup>

Children have a strong, likely innate, preference for sweet tasting substances such as sugars and artificial sweeteners. Additionally, odours often associated with sweet tasting foods and beverages (eg, fruity) also come to impart a sweet sensation, which children find highly attractive. Together, sweet tastes and sweet odours form a powerful sweet flavour mix that can be particularly attractive to children.

### Limitations

This review was not intended to include papers focused on the physiological development of taste or smell, which might have resulted in some omissions. For example, a paper on developmental changes in salt acceptability in human infants, which reported that infants under 4 months exhibited no preference for moderate concentrations of salt solutions relative to plain water, whereas infants aged 4–24 months preferred salt solutions to water.<sup>56</sup> Similarly, articles not peer-reviewed were excluded. For example, a book entitled *Odour Preferences*, by Moncrieff,<sup>57</sup> which details research on odour preferences and age, was not included. Moncrieff<sup>57</sup> showed older adults have increased tolerance for unpleasant odours versus children. Additionally, he reported while fruity odours are considered pleasant at all ages, they are particularly favoured by children.<sup>57</sup> Also excluded from this review was the National Geographic Smell Survey, which found similar results.<sup>58 59</sup>

### Implications for flavoured tobacco products

Human preference for certain types of flavours, particularly sweet flavours, is an attractive target for any industry making products for human consumption. For example, the alcohol industry has developed several premixed, ready-to-drink, sweet beverages that are popular among young people.<sup>28 32</sup> ‘Sweet’ odours, particularly those associated with fruit, are common themes when advertising these products and can make a product with alcohol levels as high as 12% more palatable.<sup>60 61</sup> This is especially relevant to sweet flavoured tobacco products as it indicates sweet flavours, combined with a psychoactive substance like alcohol, increases palatability of that substance.

Most adult smokers start smoking before age 18, a time when preference for sweet taste is still very high.<sup>62</sup> Typically, first-time smokers experience nausea, coughing or dizziness, hence the necessity of a way to mask the natural harshness of tobacco to make first experiences less negative.<sup>63</sup> If tobacco were assigned into a category described in this review, it would be bitter, the least preferred taste in every age category. Tobacco also has an unpleasant odour to children.<sup>47</sup> However, it is possible to reduce initial aversion to bitter taste by adding sugar or sodium salt.<sup>42 45</sup> This reduction in aversion persists even after sweetness is removed.<sup>42</sup> This shows the plausibility of using sweet flavours

to increase initiation of tobacco use, which will persist even in the absence of characterising flavours. Similarly, children appear to have higher preferences for sour taste than adults.<sup>41</sup>

Increasing appeal of products by adding flavours, specifically sweet flavours, has been a tobacco industry strategy for decades. For example, a 1972 report by Brown and Williamson stated:

“It’s a well-known fact that teenagers like sweet products. Honey might be considered.” The report continued, “Apples connote goodness and freshness and we see many possibilities for our youth oriented cigarette with this flavour. Apple cider is also a possibility.”<sup>64</sup>

Sweet taste is preferred not only among children and adolescents, and also by mature adults. The availability of flavoured tobacco may affect patterns of use and initiation among youth and also how adult smokers adapt to the growing market of flavoured products. Tobacco industry documents describe the potential of adult consumer demand for products offered in a variety of flavours.<sup>65</sup>

A 2013 qualitative study conducted among current e-cigarette users recruited from online forums described the role flavour plays in continued use of e-cigarettes. It compared the perceived efficacy of e-cigarettes and nicotine replacement therapies and found flavour was a component of what the authors call a ‘hobby element’: the experience of ‘mixing and matching different types of e-cigarette parts and “juice” flavours’.<sup>66</sup> Although the authors sought qualitative information to help inform hypotheses related to the behavioural facets of addiction that e-cigarettes might provide, their data also suggest that use is driven, in part, by the ability to mix different flavours. Thus, these are also flavour delivery devices.

Availability of flavoured hookah (waterpipe) tobacco is concerning, given its popularity among adolescents and young adults and the misconceptions associated with the product. In-depth interviews with college-aged students found that they thought that water filtration and flavours reduced the risks; people reported that flavoured tobacco did not contain the same ingredients as cigarettes and was less harmful than cigarettes.<sup>67</sup> One paper’s list of hookah (waterpipe) tobacco flavours included fruity/sweet flavours such as apple martini, blueberry, bubble gum, cherry cola, cotton candy, pink lemonade and strawberry banana split.<sup>67</sup> The authors concluded the herbal and fruit flavours common in hookah (waterpipe) tobacco make first experiences more palatable.<sup>67</sup>

Cigarettes are allowed to contain menthol flavour in the USA (H.R. 1256 (111th), Family Smoking Prevention and Tobacco Control Act); therefore, findings related to menthol are relevant. One paper showed menthol’s minty aroma (odour) and pungency (trigeminal or chemesthetic stimulation) decreased as people aged,<sup>53</sup> likely related to reduced sensitivity. Menthol in higher levels is added to cigarettes as a characterising flavour, but also added at lower levels to ‘brighten’ and/or ‘balance’ the taste.<sup>65</sup> Menthol stimulates taste, smell and chemesthetic receptors depending on concentration and method of delivery. Through these multiple sensory inputs, it alters the impact of smoke and modulates the irritation from nicotine.<sup>68–70</sup>

We found cherry, candy, coffee, strawberry, orange, apple and cinnamon are flavours preferred by some specific subgroups, particularly young people. The availability of flavoured tobacco products in fruit/sweet tastes known to be preferred by children, adolescents and young adults could contribute to an increase in tobacco use and initiation in the form of flavoured tobacco products. These and other flavours are available in e-cigarette cartridges, sold under categories such as ‘dessert’, ‘fruit’ and ‘other

flavours'. Similarly, sweeteners can be added to hookah, smokeless tobacco and cigars to elicit greater sweet taste. A recent study found the concentration of flavour chemicals in some tobacco products (online and retail) was higher than in popular candy and drink products. The chemical-specific flavour sensory cues they found associated with fruit flavours, such as cherry, grape, apple, peach and berry, are used in flavoured tobacco products.<sup>71</sup> Results from this review might inform policy related to the availability and/or marketing of flavoured tobacco products.

### Knowledge gaps and research opportunities

There was surprisingly little information on age differences in flavour preferences, and even less when limited to tobacco products. The field of retronasal olfaction seems particularly relevant because tobacco smoke components and other flavour chemicals used in tobacco products directly interact with the surface of the oral and nasal cavities; however, literature on this topic is scarce. This represents clear research opportunities, particularly as related to age-related responses to inhaled flavours, and whether exposure in a younger age affects preference in older age.

### What this paper adds

- ▶ The literature on flavour preference differences across ages has not been previously synthesized into a single review.
- ▶ In a review of the literature, we found 59 relevant articles.
- ▶ Sweet is a preferred flavour across ages, but youth show a stronger preference as compared to adults.
- ▶ Youth show a stronger preference for salty as compared to adults.
- ▶ Understanding flavour preferences as tested by food, confections, beverages and chemical stimuli, we can better understand how flavoured tobacco products may differentially impact youth versus adults.

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