British Journal of Nutrition (2000), **83**, 105–113

Effects of flavour amplification of Quorn® and yoghurt on food preference and consumption in relation to age, BMI and odour perception

Martijn I. Griep*, Tony F. Mets and Desire L. Massart
Faculty of Medicine and Pharmacy, Department of Pharmaceutical and Biomedical Analysis, Vrije Universiteit Brussel, Laarbeeklaan 103, B-1090 Brussels, Belgium

(Received 4 November 1998 – Revised 23 June 1999 – Accepted 23 July 1999)

Since the food habits of many elderly people are inadequate, the first experiment of the present study tested whether flavour amplification induces changes in preferences for and consumption of food and thus might result in a nutritional benefit. Two panels, one of 260 and one of 120 subjects, aged 19–98 years, took part in the study in which preferences for flavour-amplified yoghurt and Quorn® were measured. For both products, only a few of the young subjects (20 %) preferred the high flavour level; the percentage of subjects preferring the high flavour levels increased with age. These changes were highly significant. In a second experiment, participants received, under *ad libitum* conditions over 2 d in random order, a dish of yoghurt with either a high or a low flavour level. When adjusted for total consumption quantity, consumption of the highly flavoured yoghurt was not significantly correlated with age (r –0·03, $P = 0·35$). In a third experiment, odour perception was measured by determining the detection threshold for isoamylacetate. BMI values were obtained and the relationships between BMI and odour perception, age, preference and consumption were assessed in the age group 40–65 years. A significant correlation was observed between age and BMI (r 0·51, $P < 0·0005$). No significant correlation was observed between BMI and relative consumption of highly flavoured yoghurt (r –0·14, $P = 0·14$). A significant correlation was observed between BMI and preference for flavour-amplified yoghurt (r 0·35, $P <$ 0·001). However, no significant correlation was observed between BMI and odour perception (r 0·07, $P = 0·32$). With increasing age, a combined influence of age, sex, BMI and odour perception on food preference is to be expected. According to our multiple regression analysis, BMI showed a significant partial regression coefficient (standardized β 0·36, $P = 0·03$). In conclusion, flavour amplification of food for older adults deserves attention, but specific approaches, which are tailored to the candidate food systems and older adult target groups, are needed.

Age: Food preference: Odour perception: Flavour-amplified food

Sensory properties of food, such as texture and flavour, are important determinants of food choice. Flavour perception has been rated as the strongest determinant of food consumption in older adults (Rolls & McDermott, 1991). It has been suggested that poor odour perception can cause changes in food consumption, diminished food appreciation and poor nutritional state among older adults (Cain *et al*. 1990; Palumerri & Galizzi, 1992; Duffy *et al*. 1995; Griep *et al*. 1996). The average age of the population is increasing and older adults are particularly prone to developing malnutrition and multiple dietary deficiencies (Shils *et al*. 1994). The energy intake of older adults is often found to be below the recommended daily allowance, making it extremely difficult to meet requirements for vitamins and minerals (De Groot *et al*. 1992). It has been suggested that increased consumption of easily consumable micronutrient-dense products could help to assure adequate intakes of nutrients and prevent deficiencies (Van der Wielen *et al*. 1996). Nutrient-dense food products are those food products in which the ratio micronutrient : energy content is relatively high, at least for a number of micronutrients.

Flavours of food consist mainly of volatile odours and it has been suggested that enriching food by adding volatile flavours may increase preferences for particular food products (Schiffman, 1983; Ship *et al*. 1996). Compared with (saturated) fat, sugar and salt, exposure to additional amounts of flavours is generally harmless and self-limiting, showing no detrimental health effects since only small quantities, well below the maximal tolerable doses, are needed to give food a perceptibly stronger flavour level (Schiffman, 1992).

* **Corresponding author:** Dr Martijn I. Griep, present address AZ VUB Academic Hospital, c/o Professor T. F. Mets, Department of Geriatrics, Laarbeeklaan 101, B-1090 Brussels, Belgium, email Martijn.Griep@europe.ppdi.com

Previous studies with roast beef, ham and bacon have shown that enriching food with odorous flavours is effective in changing food choice. Schiffman & Warwick (1993) showed that consumption of flavour-enhanced food products is associated with improved immune function and health. Preferences for twenty food items including vegetables, meat, soup, fruit, fruit juices and pasta showed that older adults preferred the flavour-amplified samples in nineteen out of twenty food products tested (Schiffman & Warwick, 1989).

Knowledge about the effects of flavour amplification on food acceptability allows the setting of product development guidelines for the food industry and the selection of candidate food products tailored to the growing market of older adult consumers. Nutrient-dense food products seem to be the prime candidates for flavour amplification. Adding flavours to these products might make the food more appealing and increase consumption. For their nutritional benefits, we chose in this study to test whether flavour amplification induces changes in preferences for skimmed-milk yoghurt and Quorn® and whether any preferences are related to poor nutritional state. Preference for particular products might not necessarily imply increased consumption (Rozin, 1989). The older adult population, in particular the sector above 80 years, is much more heterogeneous in terms of odour perception and nutritional state than the younger population (below 40 years), and older adults suffering from poor odour perception tend to have lower nutrient intake levels compared with older adults with good odour perception (Griep *et al*. 1996). Therefore, we tested whether older adults suffering from diminished odour perception could benefit from flavour-amplified food by exploring the relationships between odour perception, nutritional state, preference and consumption of flavour-amplified food.

Subjects and methods

Subjects

For the sensory tests with yoghurt, a panel of 260 untrained subjects (196 women and sixty-four men, aged 19–98 years, mean 68·9 (SD 22·1) years) took part in this study. For the sensory tests with Quorn®, 120 other subjects participated (seventy-two women and forty-eight men; aged 20–90 years, mean 52·3 (SD 25·8) years). Older adults were recruited at four different locations in Belgium by contacting organizations for the elderly. During health exercise programmes, where the older adults were participating in sporting activities, education programmes about healthy lifestyles and social programmes, they were recruited to participate in the sensory sessions. Sensory test sessions were organized between the activities of the health exercise programme. Sensory test facilities were installed locally, using the dining rooms of the institutions where the health exercise programmes were held.

All subjects, including the young people who were recruited from the University campus and from site personnel, came to the sensory test facilities. All participants were apparently healthy, able to feed themselves, without obstructions in the nasal cavity and without acute infections. Participants with problems of alcohol abuse, mental deterioration and dementia were excluded.

Anthropometric measurements

Body weight was measured to the nearest 0·5 kg on a calibrated physician's scale. Height was measured to the nearest 0·005 m by a horizontal sliding bar attached to the physician's scale. BMI was calculated as weight divided by height squared (kg/m^2). The measurements were obtained by a total of five observers who were all trained by a single observer (M. G.) to minimize observer bias.

Odour perception

For the evaluation of odour perception, detection threshold for isoamylacetate (fruity banana–pear odour) was determined as the lowest detectable concentration odour. The method has been widely used with many substances and calibrated in many previous studies (Laska & Hudson, 1991; Griep *et al*. 1995). The substance has been used in several studies and detection thresholds have been shown to be a reliable general and objective measure of olfactory performance (Doty & Kobal, 1995), allowing interindividual comparisons.

The isoamylacetate solutions were prepared according to the procedure described by Laska & Hudson (1991). The substance had a nominal purity of $>99\%$ and was diluted in diethylphthalate. GC verification showed that headspace concentrations of freshly prepared solutions in the bottles remained constant over the whole testing period. Dilution series of fourteen concentration steps were prepared starting at 25 g/l with a dilution factor of 5 between steps. Odours were presented in 250 ml polyethylene squeeze bottles containing 40 ml solution and equipped with a flip-up spout with an interchangeable nose-piece (Teflon®). Squeezing the bottle ejected an odourized stream of air through the spout while the subject waved the spout back and forth beneath the nostrils. After use, the bottle was closed immediately and briefly shaken (2 s) to re-establish equilibrium in the headspace of the bottle for the next experiment. As two bottles were available for each concentration, the same bottle was never used in subsequent pairs. The subject received a pair of bottles (one of the six blanks containing the solvent only and one containing the odour) and was asked to sniff and then to indicate which of the two smelled stronger, the so-called forced choice paradigm. Test subjects were 'forced' to make a choice between the bottles and if the choice was very difficult, a guess was required. Forced choice procedures are particularly suited for making objective comparisons between different groups (Weiffenbach, 1989; Doty, 1991). For each pair of bottles, the order of presentation of the blank or the bottle with the odour was randomly divided. An inter-trial interval of 30 s was chosen to allow recovery from adaptation. Detection thresholds were determined by using an ascending method of limits, starting at the lowest of the fourteen prepared concentrations (Stevens & Cain, 1985). Threshold was reached when five subsequent pairs were correctly indicated. All measurements were carried out in well-ventilated and quiet rooms.

Food systems for flavour amplification

Skimmed-milk yoghurt was chosen as a major source of Ca and for its potential beneficial effects on general health (Rafter, 1995; Schiffrin *et al*. 1995). The meat substitute, Quorn® (Marlow Foods, Stokesley, North Yorkshire, UK, based on *Fusarium graminearum*) enriched with meat flavour, was chosen for its favourable texture, low saturated fat content, high contents of starch, riboflavin, and vitamin B_{12} and high-quality protein.

The concentration ranges of flavours in the food samples were guaranteed by scientists of Perlarom s.a. (Louvain-La-Neuve, Belgium). All flavours used were mixtures of odorous molecules extracted from natural products or synthesized after chemical analysis of the natural product. Optimal sensory quality of the food systems was assessed during extended sensory testing with healthy volunteers at the university campus. During these pilot studies, perceptibly equal flavour intensities for both products were created. In addition, obvious perceptible differences between high and low flavour concentrations in the samples were created, while preparation and logistical procedures were standardized. The sensory differences were created for odorous compounds only, while the other sensory characteristics such as taste, colour and texture were held constant.

For the preparation of the yoghurt samples, 25·0 g simplex sugar syrup (Pharmacopoeia standard) was mixed with 0·200 or 1·000 ml strawberry flavour (Perlarom s.a.), for low and high flavour levels respectively. Skimmed-milk yoghurt (375·0 g; Delhaize, Brussels, Belgium) was mixed with the syrup until the mixture was homogeneous.

For the preparation of the Quorn® samples, 115 g purified water (Pharmacopoeia standard) was boiled, and a mixture of chicken spices, marjoram (Liebig Benelux, Beveren-Waas, Belgium) and chicken flavour (Perlarom) was mixed with the water. Quorn® pieces (90 g) approximately equal in shape, were added to the high- and low-flavour mixtures. Marjoram was chosen as it mainly stimulates the olfactory receptors (Cain *et al*. 1990) and is frequently recommended in recipes for Quorn®. The Quorn® pieces were boiled for 10 min and thereafter soaked for 16 h at 5° in sealed glassware. For highly flavoured Quorn®, 5·5 g chicken spices, 1·1 g marjoram and 10 ml chicken flavour were used. For low-flavoured Quorn®, 1·0 g chicken spices, 0·55 g marjoram and 5 ml chicken flavour were used. After soaking, the Quorn® pieces were fried at 150° for 50 s.

Preference and consumption measurements

In random order, participants received in small identical cups pairwise, two food samples (20 g) at the same time, one containing the high food flavour level, the other the low flavour level. The test subjects were asked to indicate if they perceived a difference between the two samples. If so, subjects were asked to tell in their own words which of the two was preferred and why. The subjects were also asked to give a score from 1 to 10 to indicate their appreciation. For validity reasons, and in order to check the responses, making sure that the responses could not be attributed to chance, excluding chance reporting, over-reporting or social desirable responses, the preference responses were checked by both the numbers and qualitative responses. If inconsistencies occurred or serious doubts arose about the correctness of the response, correction was possible after probing or repeating the questions.

The following instruction was used: ‘You will now receive two cups of yoghurt (or Quorn®). Could you taste them and say whether you taste a difference between the two samples? If there is a difference, you may say which is the most appetizing for you. You may also give a score from one to ten to each cup to indicate how much you like each sample. A 1 means not appealing at all, while a 10 indicates excellent’.

Independently of the preference measures, participants received over 2 d, in random order, a dish of 400 g yoghurt with either a high or a low flavour level. The dishes were specially provided for the experiment and were supplied under controlled conditions between the usual meals of the participants. Testing days were carefully selected by consulting the management of the institutes to make sure that the normal meals for the participants on both testing days were comparable in terms of energy contents and serving time. Sufficient yoghurt (400 g) was available to allow participants to eat as much as they desired, thus allowing consumption levels to be compared. On each testing day, all dishes were prepared individually under the same conditions. Testing took place in clean, ventilated, neutral dining rooms that were, at that time, used for this experiment only, and were free of smoke or loud noise. Before the sessions, subjects were interviewed to verify that they did not consume excessive or minimal amounts during their meals and if they did, they were excluded from further statistical analysis. Participants were naive with respect to the details of the study and it was verified that subjects added no sugar or other substances to the yoghurt. To measure the differences in consumed quantities, portions were weighed before and after the session. Due to logistical limitations, it was not possible to conduct the consumption experiment with Quorn®.

The following instruction was used: ‘You will now receive a cup of yoghurt of which you may eat as much as you want. As you will see, the cups are rather big, but you don’t have to empty them completely. You may eat as much as you like and if you have had enough, just leave the rest. Please do not give away or change your cup’.

Statistics

The preference scale was not anchored on a common sensory unit and, therefore, the relative preference score was calculated as the difference in preference between high and low flavour levels. If the subject had no preference, a preference score of 0 was assigned.

Since it was expected that some subjects would consume more or less yoghurt irrespective of the flavour level, and to correct for absolute consumption quantity, the difference in consumed quantities of high- and low-flavour yoghurts was divided by the consumption quantities of the low- and high-flavour yoghurts.

The Kolmogorov–Smirnov test was used to test the normality of the distribution. Spearman rank correlations were calculated and tested for significance by ranking the

Table 1. Distribution of subjects taking part in the yoghurt sessions of the present study, by age, sex and BMI
(Mean values and standard deviations)

Age group...	< 40 years		40–60 years		61–80 years		> 80 years	
Sex...	Men	Women	Men	Women	Men	Women	Men	Women
n...	15	18	10	13	20	78	19	87
BMI (kg/m^2)								
Mean	22·4	21·6	29·8	27·1	26·6	26·9	26·3	25·7
SD	2·67	3·85	3·48	2·63	3·30	4·56	3·45	4·12

subjects on each of the variables. To test the hypothesis that the two groups were equal, the Mann–Whitney test was applied. When the relationship between two categorical variables was assessed, the χ^2 test was applied (e.g. sex and preference). To test the combined contribution of different independent variables on the dependent variable of interest, multiple regression was used. Statistical tests were applied with the Statistical Package for the Social Sciences software (version 4, 1990; SPSS Benelux, Gorinchem, The Netherlands). The criterion for statistical significance was $P < 0·01$ for the univariate statistical results and $P < 0·05$ for the multiple regression results.

Ethical considerations

All subjects gave informed consent after full explanation of the general procedures and products used during the sensory tests. Exposure to additional amounts of the flavours was harmless since the quantities needed to give the food products a perceptibly stronger flavour level were well below the maximal tolerable doses. The protocols were approved by the Medical Ethical Committee of the Vrije Universiteit Brussel Faculty of Medicine and Pharmacy.

Results

Tables 1 and 2 show the age, sex and BMI distributions of the two populations under investigation. Age, relative consumption and relative preference did not have normal distributions (Kolmogorov–Smirnov test, $P = 0·003$, 0·016 and 0·003 respectively). BMI and odour perception were normally distributed (Kolmogorov–Smirnov test, $P = 0·24$ and 0·63 respectively). The female subjects in this study tended to have a lower BMI and were slightly older than the males (Mann–Whitney test, $P = 0·003$).

Age and preference for yoghurt and Quorn®

The relative numbers of subjects preferring high- and low-flavour-level yoghurt and Quorn® in the different age groups were calculated, including the numbers of subjects with no preference. In Table 3, the results are shown. For Quorn®, the relative number of subjects preferring the high flavour level increased significantly with age (one-sided test, $P < 0·005$). In the youngest group (< 40 years), only 20 % preferred the high flavour level, among those aged 40–60 years, 64 % preferred the high flavour level, among those aged 61–80 years, 63 % preferred the high flavour level and among those aged 80 years or more, 58 % preferred the high flavour level.

For yoghurt, a similar significant increase with age was obtained (one-sided test, $P < 0·005$). In the youngest group (< 40 years), only 21 % preferred the high flavour level, among those aged 40–60 years, 25 % preferred the high flavour level, among those aged 61–80 years, 42 % preferred the high flavour level and among those aged 80 years or more, 44 % preferred the high flavour level.

Expressed on a 10 point preference scale and subtracting the rating of the low-flavour product from that for the high-flavour product, a significant correlation was observed between preference for high-flavour-level food and age (r 0·25, r 0·30, $P < 0·0005$ for yoghurt and Quorn® respectively). Figs. 1 and 2 show that the relative preference for high-flavour-level yoghurt and Quorn® increased with age, since for Quorn®, below 40 years, 20 % of the points along the y-axis are positive, while 58 % of the points along the y-axis are positive for subjects above 80 years. For yoghurt, in subjects below 40 years, 21 % of the points along the y-axis are positive, while 44 % of the points along the y-axis are positive in those above 80 years.

Tables 3 and Figs. 1 and 2 also show that the relative number of subjects without preference increased significantly with age, reaching 25 % in the age group > 80 years

Table 2. Distribution of subjects taking part in the Quorn® sessions of the present study, by age, sex and BMI
(Mean values and standard deviations)

Age group...	< 40 years		40–60 years		61–80 years		> 80 years	
Sex...	Men	Women	Men	Women	Men	Women	Men	Women
n...	23	24	7	12	10	22	8	14
BMI (kg/m^2)								
Mean	21·8	20·9	30·2	27·9	25·1	27·2	25·1	24·8
SD	2·90	2·78	2·67	2·95	2·90	3·40	2·80	3·56

Table 3. Proportions (%) of subjects of different age groups showing a preference for different flavour levels in Quorn® and yoghurt

	Quorn®				Yoghurt			
Age group (years)...	< 40	40–60	61–80	> 80	< 40	40–60	61–80	> 80
Preference for:								
High flavour	20	64	63	58	21	25	42	44
Low flavour	73	36	32	19	77	64	41	31
No preference	7	0	5	23	2	11	17	25

(one-sided test, $P < 0.05$). The preference was measured on a continuous scale, where for those with no preference, a value of 0 was assigned. Despite the increased number of 0 values with age, preference showed a significant positive correlation with age (r 0·25, $P = 0.0005$). Recalculation of the correlation coefficient when the subjects with score 0 were left out did not change the magnitude of the correlation coefficient (r 0·26 instead of 0·25, $P = 0.0005$).

No significant differences were observed in preference for high or low flavour level between men and women (χ^2 test, $P = 0.068$).

Age, preference and consumption of flavour-amplified yoghurt

The relative consumption of high-flavour-level yoghurt, adjusted for total consumption quantity, was not significantly correlated with age (r –0·03, $P = 0.35$), as illustrated in Fig. 3. No significant correlation was observed between relative preference and relative consumption of high-flavour-level yoghurt (r –0·0007, $P = 0.496$).

Nutritional state, odour perception, preference for and consumption of flavour-amplified yoghurt

BMI is a less valid measure in people over 65 years of age, due to the changes in posture and the potential error in measuring height. Furthermore, a large rise in BMI occurs between the age groups < 40 and 40–60 years and it was expected that the age–BMI relationship would be non-linear. Examination of the relationships between age, BMI, odour perception, preference and consumption was

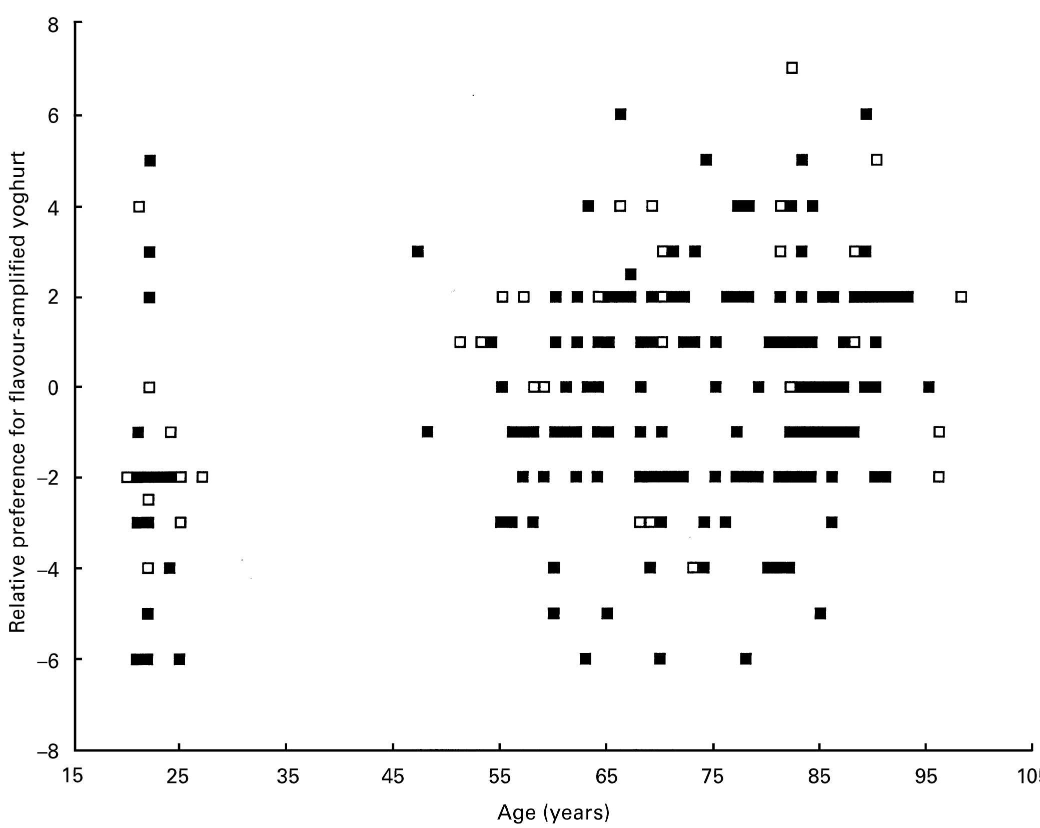

Fig. 1. Relationship between age and preference for flavour-amplified yoghurt in men (□) and women (■) in the present study (n 260). The relative preference for flavour-amplified yoghurt represents the difference between scores for the high- and low-flavoured yoghurts, expressed on a 10 point preference scale (r 0·31, $P < 0.005$).

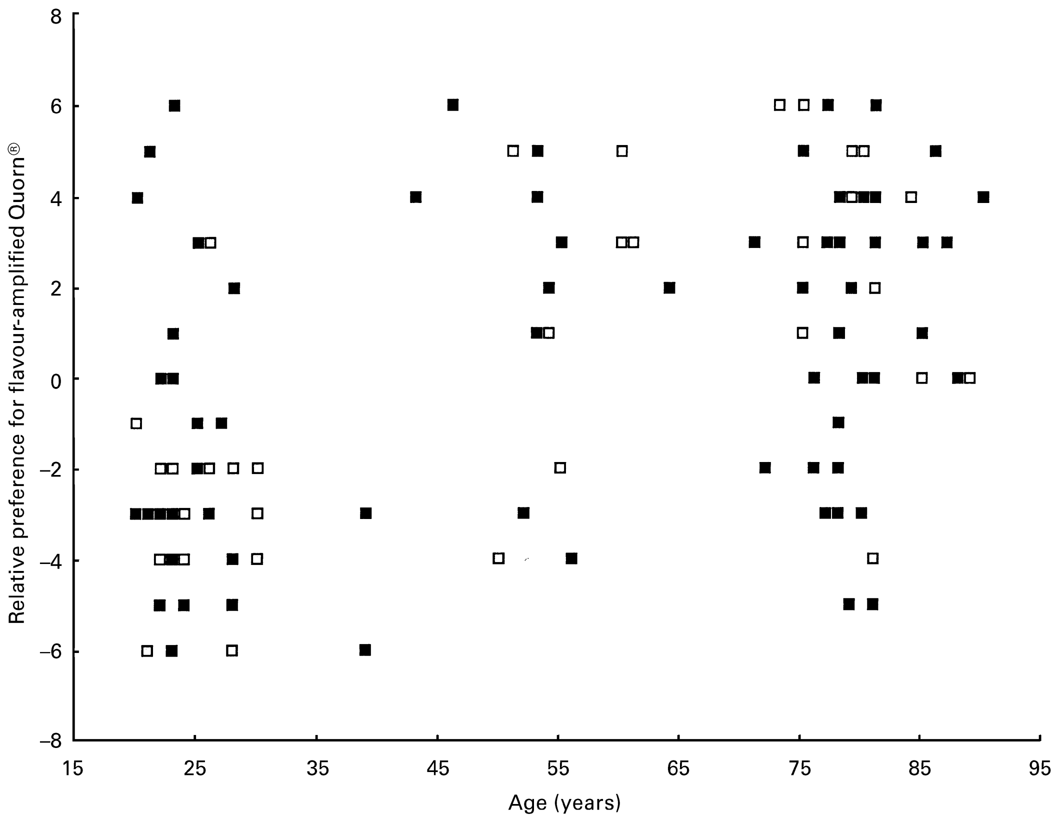

Fig. 2. Relationship between age and preference for flavour-amplified Quorn® in men (□) and women (■) in the present study (*n* 120). The relative preference for flavour-amplified Quorn represents the difference between scores for the high- and low-flavoured Quorn® samples, expressed on a 10 point preference scale (r 0·26, $P < 0·005$).

therefore restricted to people aged 40–65 years. The relationships between odour perception, BMI, age, preference and consumption were assessed in the age group >40 years since odour perception is generally not impaired in individuals below 40 years and shows little variety compared with older adults (Griep *et al*. 1995). Since odour perception was only measured for the panel of the yoghurt session, these relationships were not available for the Quorn® panel.

Among the people aged between 40 and 65 years, a significant correlation was observed between age and BMI (r 0·51, $P < 0·0005$) indicating that younger people have relatively more lean body mass than older people. No significant correlation was observed between BMI and relative consumption of high-flavour-level yoghurt (r –0·14, $P = 0·14$). As can be seen in Fig. 4, a significant correlation was observed between BMI and preference for flavour-amplified yoghurt (r 0·35, $P < 0·001$). However, no significant correlation was observed between BMI and odour perception (r 0·07, $P = 0·32$).

A significant inverse correlation was observed between age and odour perception (r –0·52, $P < 0·0005$). No correlation was observed between odour perception and relative consumption of high-flavour-level yoghurt (r –0·0077, $P = 0·461$) or between preference for flavour-amplified yoghurt and odour perception (r –0·029, $P = 0·344$).

Among the people aged 65 years or more, a considerable number of subjects had no preference and the subjects without preference for flavour-amplified yoghurt had significantly poorer odour perception compared with those with a preference (Mann–Whitney test, $P = 0·005$).

Combined effects of age, nutritional state, odour perception and sex on preference and consumption

Since among people aged 65 years or less, the variables age, odour perception, sex and nutritional state are interrelated, the separate contributions of different independent variables to the dependent variables preference for and consumption of yoghurt were tested for significance by multiple regression. Due to the categorical nature of sex, this variable was dummy coded (male 0, female 1). In Table 4, the full regression equations are shown and when yoghurt consumption was taken as dependent variable, none of the parameters showed significant partial regression coefficients ($P > 0·05$), confirming the univariate results. When yoghurt preference was taken as dependent variable, BMI showed a significant partial regression coefficient (standardized β 0·36, $P = 0·03$), confirming the univariate result that when BMI increases, preference for flavour-amplified food increases.

Discussion

Our results indicate that flavour amplification can influence food preferences for both Quorn® and yoghurt. Compared with young subjects, older adults reacted positively to the

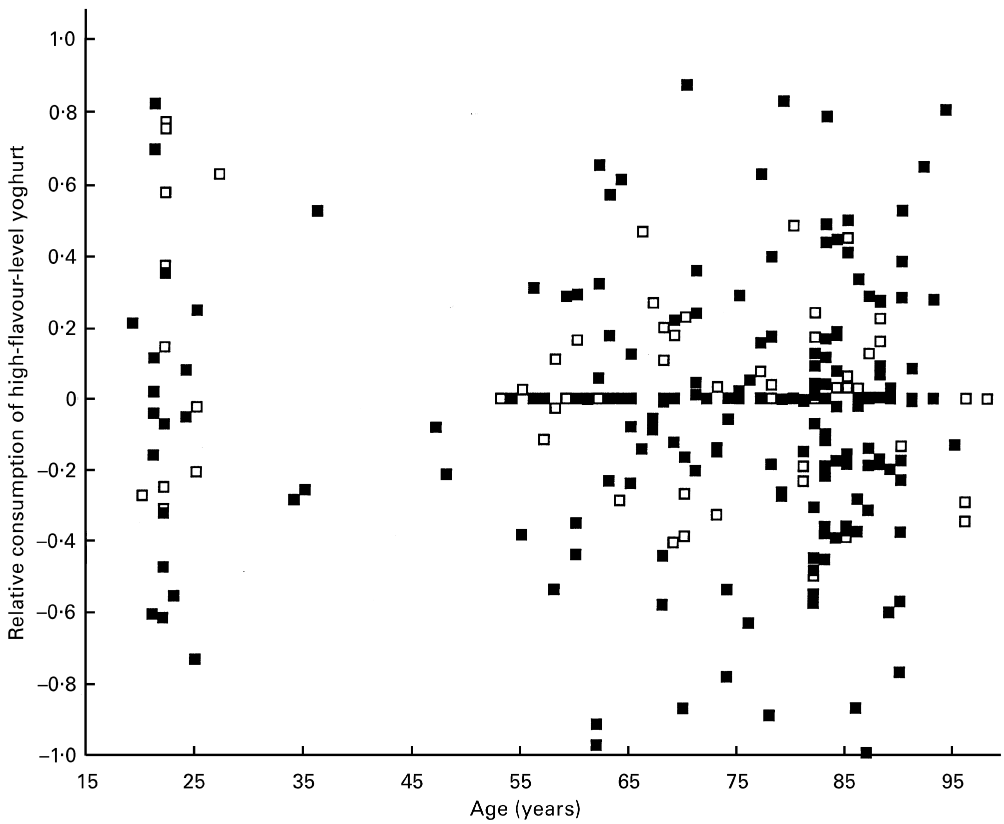

Fig. 3. Relationship between age and relative consumption of flavour-amplified yoghurt by men (□) and women (■) in the present study (*n* 260). Relative consumption is the consumption of high-flavoured yoghurt divided by the total consumption of yoghurt (*r* –0·06, *P*=0·18).

flavour-amplified Quorn® and yoghurt. With age, a strong increase in the number of subjects preferring the high flavour level was observed. Also, the number of subjects not showing a preference increased with age. Although in our study, only two flavour concentration steps were used with perceptibly equal flavour levels of Quorn® and yoghurt, the proportion of subjects aged 40–60 years preferring the high-flavour-level yoghurt was 25 %, but reached 64 % for Quorn®. For the subjects aged 61–80 years, the proportions were also different: 42 % and 63 % respectively. With regard to the optimal preferred flavour concentrations, our results are in agreement with studies of De Graaf *et al.* (1994, 1996) who found that age-related changes in pleasantness of food flavours were different for different types of flavours.

The results of the consumption measurements of flavour-amplified food are less clear and the mechanisms seem to be contradictory. No relationship was found between an increased consumption of flavour-amplified food and age, nor between preference and consumption. However, after adjusting for other variables in the multivariate model, a significant relationship was observed between BMI and preference for flavour-amplified food showing that lean subjects prefer less highly flavoured food in contrast to persons with high BMI. Older adults suffering from poor odour perception might benefit from flavour-amplified food since the increased flavour level compensates for sensory loss (Griep *et al.* 1996). Along this line, in our present study, a tendency was observed that subjects above 65 years without preference for the high or the low flavour level had a poorer odour perception compared with subjects with a clear preference. However, no significant relationship was found between odour perception and BMI. Adding flavours to food may influence preferences and could compensate for diminished odour perception with age. It is, however, not clear if this effect would prevent decreases of food intake or restore the nutritional state.

The observed controversy concerning the relationship between odour perception, nutritional state and food preference may be due in part to the effect of general health. It has been suggested that for odour perception, health status might be more important than age (Griep *et al.* 1995). Although individuals who were not apparently healthy were excluded from our study, the population under investigation was heterogeneous with regard to general health. Many studies have shown that odour perception is related to medical condition and medication use (Schiffman, 1992; Ship & Weiffenbach, 1993; Doty & Kobal, 1995) for which our results did not control, and it therefore seems logical that our results show a weak relationship between odour perception, nutritional state and food preference.

The effect of age on increased preference for flavour-amplified food is clear, but a discrepancy was observed between preference and consumption. Preference for a particular food does not necessarily imply increased consumption, whereas increased consumption can also occur

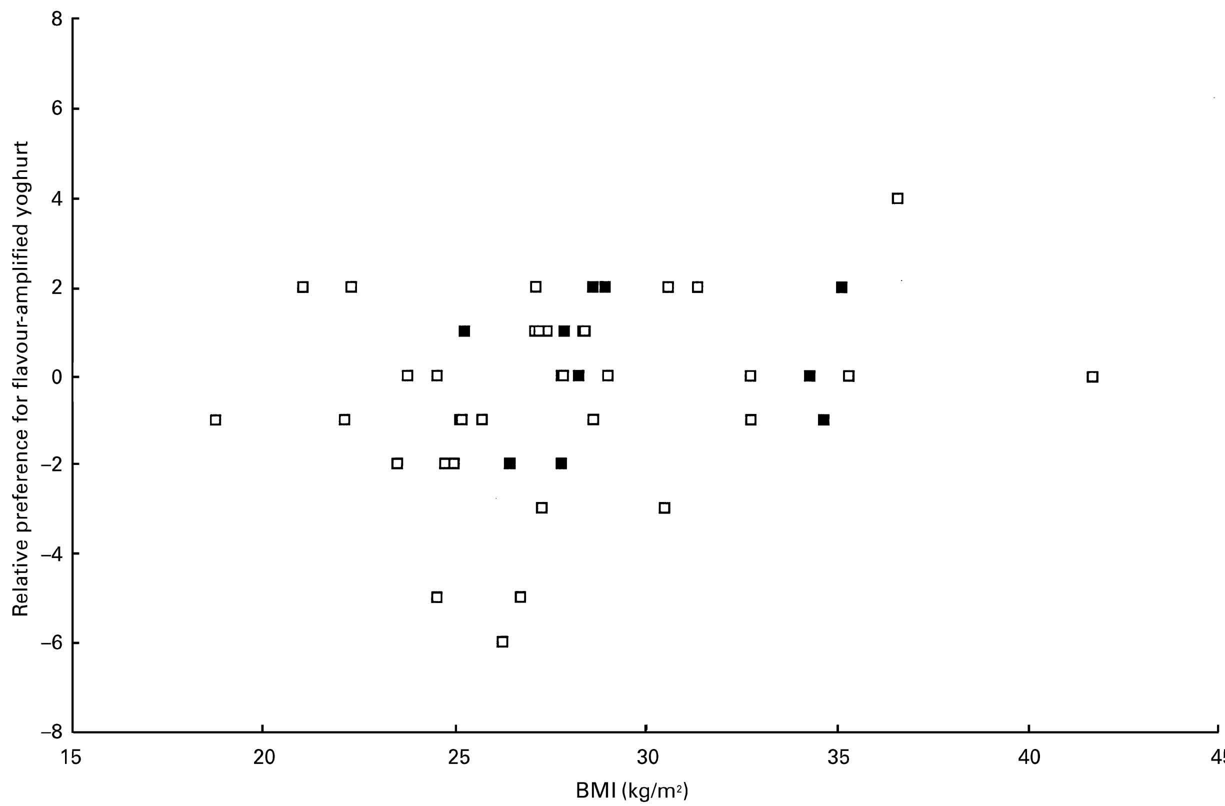

Fig. 4. Relationship between BMI and preference for flavour-amplified yoghurt among men (□) and women (■) in the 40–65 years age group of the present study (*n* 43). The relative preference for flavour-amplified yoghurt represents the difference between scores for the high- and low-flavoured yoghurts, expressed on a 10 point scale (r 0·35, $P=0·001$).

without increased preference. This discrepancy between preference and consumption can partly be explained by a self-limiting mechanism of flavour amplification due to sensory-specific satiety (Rolls & McDermott, 1991). High preference for flavour-amplified food does not lead to overconsumption, as after having consumed a substantial amount, subjects seek variety and do not consume more of the high flavour level. Suggestions have also been made that flavour amplification restores sensory-specific satiety in older adults, leading to a more varied food selection (Rolls & McDermott, 1991). Furthermore, the aged population is heterogeneous in nature in terms of health status, sensory capacities, nutritional state, living conditions, socio-economic factors, attitudes, perceived risk and well-being which might affect food choice. Therefore, different mechanisms exist leading to preference and consumption, and consumption is not necessarily mediated by preference.

Table 4. Regression equations with relative consumption of and preference for flavour-amplified yoghurt as dependent variables

Dependent variable . . .	Consumption (R^2 0·18)		Preference (R^2 0·18)	
Independent variable . . .	β*	P	β*	P
Sex	0·00	0·97	−0·15	0·38
Odour perception	−0·08	0·72	−0·05	0·75
BMI	−0·06	0·79	0·36	0·03
Age	0.27	0·22	0·054	0·75
Preference	−0·27	0·28	NA	

NA, not applicable.
* Partial regression coefficient.

In previous studies, food preferences of older adults were measured by using a visual scale ranging e.g. from unpleasant to pleasant, or by applying a magnitude matching scaling procedure. Considerable controversy exists about appropriate scales for studies with older adults (Stevens & Cain, 1985; Bartoshuk, 1989; Murphy, 1989; Doty & Kobal, 1995). In our study, it was necessary to find simple and reliable preference measures that could be used in the older adult population at large where poor vision, comprehension, motivation or moderate health problems might occur. Therefore, a short and concise procedure with a high accuracy was devised to measure preferences among the older adults, without extended training, task requirements or memory demands. The numbers were only used in a quantitative way by subtracting the score given to the low flavour level from the score given to the high flavour level. Therefore, the lack of reference values and intersubject agreement of the scale was not a problem since each subject served as his or her own control and the numbers were only used in a relative way.

The favourable texture of Quorn®, which is similar to but softer than meat, allows the optimal release of flavours during chewing. Therefore, declining chewing ability due to wearing of dentures can be compensated by texture enhancement, making food chewable by addition of functional fibre to soften textured food products (Palummeri &

Galizzi, 1992). However, these results should be treated with caution, since they are only based on preference measurements under controlled conditions and in a selected older adult population that did not reject Quorn®.

Furthermore, our results do not show whether improved preference would continue or could be generalized to a larger range of candidate food products for flavour amplification. Testing a wider range of nutrient-dense food products that are beneficial from the nutritional point of view seems worthwhile. In this sense, food products that are familiar to the aged population are probably better candidates for flavour amplification as food preferences of older adults are difficult to change and are based on life-long habits. Acceptability of flavour-amplified food for consumers under real-life conditions, including additional factors that determine food choice such as dental status, socio-economic factors, attitudes and perceived risk (Rozin, 1989) deserves further study.

In conclusion, flavour amplification of food supply for older adults deserves attention, but specific approaches which are tailored to the candidate food systems and older adult target populations are needed.

Acknowledgements

The authors gratefully thank the AIR program of the Commission of the European Communities for financial support. For assistance with data collection we thank the ‘Liberale Beweging voor Volksontwikkeling’, Brussels, Belgium, Annelies Hustings, Erica Joris, Jolanda Noordoven and the following retirement homes in Belgium: ‘Heilig Hart’ (Putte), St Jozef, Regina Coeli (Brugge), Les Fuchsias, Romana, Andante, Heysel, Aux Deux Parcs (Brussels), Wilgenhof, Mater Dei, Van der Stokken (Pajottenland). For generous supply of chicken and strawberry flavours and technical advice we thank Perlarom s.a., Louvain-La-Neuve, Belgium.

References

Bartoshuk LM (1989) Taste: robust across the age span. *Annals of the New York Academy of Sciences* **561**, 65–76.

Cain WS, Reid FR & Stevens JC (1990) Missing ingredients: aging and the discrimination of flavour. *Journal of Nutrition of the Elderly* **9**, 3–15.

De Graaf C, Polet P & Van Staveren WA (1994) Sensory perception and pleasantness of food flavours in elderly subjects. *Journal of Gerontology* **49**, P93–P99.

De Graaf C, Van Staveren WA & Burema JA (1996) Psychophysical and psychohedonic functions of four common food flavours in elderly subjects. *Chemical Senses* **21**, 293–302.

De Groot LPGM, Hautvast JGAJ & Van Staveren WA (1992) Nutrition and health of elderly people in Europe: The EURONUT-SENECA study. *Nutrition Reviews* **50**, 185–194.

Doty RL (1991) Influence of aging on human olfactory function. In *The Human Sense of Smell*, pp. 181–199 [DG Laing, RL Doty and W Breipohl, editors]. Berlin: Springer Verlag.

Doty RL & Kobal G (1995) Current trends in the measurement of olfactory function. In *Handbook of Olfaction and Gustation*, pp. 191–227 [R Doty, editor]. New York, NY: Marcel Dekker.

Duffy VB, Backstrand JR & Ferris AM (1995) Olfactory dysfunction and related nutritional risk in free-living, elderly women. *Journal of the American Dietetic Association* **8**, 879–887.

Griep MI, Mets TF, Vercruysse A, Cromphout I, Ponjaert I, Toft J & Massart DL (1995) Food odour thresholds in relation with age, nutritional and health status. *Journal of Gerontology* **50**B, B407–B414.

Griep MI, Verleye G, Mets TF & Massart DL (1996) Variation in nutrient intake with dental status, age and odour perception. *European Journal of Clinical Nutrition* **50**, 816–825.

Laska M & Hudson RA (1991) Comparison of the detection threshold of odour mixtures and their components. *Chemical Senses* **16**, 651–663.

Murphy C (1989) Aging and chemosensory perception of and preference for nutritionally significant stimuli. *Annals of the New York Academy of Sciences* **561**, 251–266.

Palummeri LT & Galizzi G (1992) Aspects concerning the elderly consumer with emphasis on food consumption. *Age & Nutrition* **3**, 11–16.

Rafter JJ (1995) The role of lactic acid bacteria in colon cancer prevention. *Scandinavian Journal of Gastroenterology* **30**, 497–502.

Rolls BJ & McDermott TM (1991) Effects of age on sensory-specific satiety. *American Journal of Clinical Nutrition* **54**, 988–996.

Rozin P (1989) The role of learning in the acquisition of food preference by humans. In *Handbook of the Psychophysiology of Human Eating*, pp. 205–231 [R Shepherd, editor]. Chichester: Wiley.

Schiffman S (1983) Taste and smell in disease. *New England Journal of Medicine* **308**, 1275–1279.

Schiffman S (1992) Olfaction in aging and medical disorders. In *Science of Olfaction*, pp. 500–526 [MJ Serby and KL Chobor, editors]. New York, NY: Springer Verlag.

Schiffman S & Warwick ZS (1989) Use of flavour-amplified foods to improve nutritional status in the elderly. *Annals of the New York Academy of Sciences* **561**, 267–277.

Schiffman S & Warwick ZS (1993) Effect of flavour enhancement of foods for the elderly on nutritional state: food intake, biochemical indices and anthropometric measures. *Physiology and Behavior* **53**, 395–402.

Schiffrin EJ, Rochat F, Link-Amster H, Aeschlimann JM & Donnet-Hughes A (1995) Immunomodulation of human blood cells following the ingestion of lactic acid bacteria. *Journal of Dairy Science* **76**, 1819–1828.

Shils ME, Olson JE & Shike M (1994) *Modern Nutrition in Health and Disease*, 8th ed. Philadelphia, PA: Lea & Febiger.

Ship JA, Pearson JD, Cruise LJ, Brant LJ & Metter EJ (1996) Longitudinal changes in smell identification. *Journal of Gerontology* **51**A, M86–M91.

Ship JA & Weiffenbach JM (1993) Age, gender, medical treatment and medication effects on smell identification. *Journal of Gerontology* **48**, M26–M32.

Stevens JC & Cain WS (1985) Age-related deficiency in the perceived strength of six odorants. *Chemical Senses* **10**, 517–529.

Van der Wielen RPJ, de Wild GM, De Groot LCPGM, Willibord HL, Hoefnagels HL & Van Staveren WA (1996) Dietary intakes of energy and water-soluble vitamins in different categories of aging. *Journal of Gerontology* **51**A, B100–B107.

Weiffenbach JM (1989) Assessment of chemosensory functioning in aging: subjective and objective procedures. *Annals of the New York Academy of Sciences* **561**, 56–65.