Consumer preference attributes for alternative food products

Jan Top, Mariëlle Timmer, Lorijn van Rooijen

PUBLIC

WAGENINGEN
UNIVERSITY & RESEARCH

Consumer preference attributes for alternative food products

Authors: Jan Top, Mariëlle Timmer, Lorijn van Rooijen

Institute: Wageningen Food & Biobased Research

This study was carried out by Wageningen Food & Biobased Research, subsidised by the Dutch Ministry of Agriculture, Nature and Food Quality and commissioned by Wageningen Food & Biobased Research.

Wageningen Food & Biobased Research
Wageningen, February 2023

Public

Report 2375
DOI: 10.18174/587331

WAGENINGEN
UNIVERSITY & RESEARCH

WFBR Project number: 6234205000
BAPS number: KB-37-001-005
Version: Final
Reviewer: G. Simsek-Senel
Approved by: H. Wensink
Carried out by: Wageningen Food & Biobased Research
Subsidised by: the Dutch Ministry of Agriculture, Nature and Food Quality
Commissioned by: Wageningen Food & Biobased Research
This report is: Public

 This report can be downloaded for free at https://doi.org/10.18174/587331 or at www.wur.eu/wfbr (under publications).

PO box 17, 6700 AA Wageningen, The Netherlands, T + 31 (0)317 48 00 84, E info.wfbr@wur.nl, www.wur.eu/wfbr.

Contents

Summary

Digital dietary coaches can supplement current approaches for guiding consumers towards healthier behavior. In addition to taking into account the individual client's health status, digital coaches must also link to her or his personal preferences and habits and to any contextual factors such as location and time of the day. We address the question which food attributes are needed to generate an advice that is fully personalized and situational. In the first part of this study, we have made a systematic analysis of food item attributes and the way in which they are used in making food choices. We distinguish between (1) food attributes as such, (2) consumer attributes (preferences, profile, habits, etc.) and (3) context attributes (time, occasion, situation, etc.). One source for finding attributes is human behavior theory. In addition, we apply a more empirical approach by analyzing attributes that dietitians and food experts use in practice. In the second part of this study we have asked consumers to indicate which food selection criteria they use in practice. We list the sets of attributes and discuss how they can be used to automatically infer preferred food items from personal and situational data. Although fully automatic generation of food alternatives is not yet possible, dietitians and life style coaches can benefit from the data that is already available. A number of web services is currently under development to access the data programmatically, for example in dietary apps.

1 Introduction

One way of making consumers adopt a healthier (and possibly more sustainable) diet is by providing a personalized dietary app. In this paper we address the question which food attributes are needed to generate an advice that is fully personalized and situational. We assume that proper use of these attributes in the advice will motivate consumers to accept and maintain the proposed improvements of their diet.
Digital dietary coaches have the potential to supplement traditional approaches for guiding consumers towards healthier behavior (1). They can give more frequent and situational support, and extend the work of professional dieticians to a larger audience. However, a digital coach has to be able to adapt its advice to the individual client in order to be effective, just like the professional dietitian. In addition to taking into account the individual client's health status, it must also link to her or his personal preferences and habits and to any contextual factors such as location and time of the day. As a consequence, the system needs to predict which food products and ingredients will be accepted by an individual consumer in a specific situation.
Current practice is that there are thousands of food products available in the supermarket, but consumers only vary between a small set of unique products. Also dietitians have a more or less standard repertoire of food product alternatives, from which they make a selection in consultation with their client. In this selection process they more or less implicitly apply certain rules that relate to personal, cultural and situational preferences. An automated approach could in principle use the predefined and limited set of alternatives, but given its computational power and memory, we propose to select product alternatives from the complete set of all products. This allows for a broader set of alternative products and enables more personalization.
Therefore we need to develop an algorithm to predict which alternative is suitable for which person at which moment. Such an algorithm can take into account many variables, and may also give useful suggestions which dietitians and their clients did not imagine yet. We claim that this may lead to new and more personalized suggestions. However, it will be a challenge to make the needed selection rules and associated attributes explicit.
In this research we address the question: 'Which food attributes (and attribute values) are needed to select acceptable food item alternatives and how are they related to personal and situational conditions?'. For example, the attribute *general food category* has values such as *vegetable, fruit, cereal, fish, meat,* etc. These values relate to the consumer attribute *life style*, and particular its value *vegetarian*. A vegetarian accepts *vegetable, fruit, cereal* but not *meat.* This example also shows that some terms used in practice need further specification, as some *vegetarians* accept *fish*, whereas others do not. In this example, we may assume that food products that are in the same category are often considered acceptable alternatives for each other. For example, people can easily accept substitution of *pork* by *chicken*. Replacing *pork* by *tofu* crosses the borders of these categories and is not appreciated by everyone. An example of a situational attribute is *eating moment*, with values such as *breakfast, bread meal, hot meal, snack*, etc. Whether one associates a product with one of these meal moments is culture dependent and differs between people. The notion *bread meal* itself is already culture-specific.
Our ultimate goal is to develop an algorithm that automatically selects acceptable food products. Automation requires making knowledge rules explicit, either by knowledge elicitation or machine learning approaches. In this paper we focus on elicitation of attributes and the relations between them from experts and literature. The algorithms that implement the found knowledge rules will be used in our Personalized Dietary Advice services library. Using these services, dietary apps will be able to provide suggestions that are beyond current personalization efforts.
It is important to note that we deliberately do not include 'health impact' or 'environmental impact' as preference attributes. In our approach we assume that these attributes are indicators that are to be optimized for *any* individual and in *any* situation. The procedure in generating a personal advice is then first to select a set of food items that are acceptable from a preference point of view and next order these in terms of health or environmental impact, where health impact may again depend on specific personal characteristics. In that way, users can still decide which suggestion is most acceptable for them.

2 Materials and methods

For making a systematic analysis of food item attributes and the way in which they are used in making food choices, we need to make a distinction between (1) food attributes as such, (2) consumer attributes (preferences, profile, habits, etc.) and (3) context attributes (time, occasion, situation, etc.). The idea is that once the consumer profile and context conditions are known, the required product attributes and their values can be derived. In this way we can establish a systematic way to automatically propose the most suitable alternative for each individual case. With these three sets of attributes we can formulate knowledge rules, with which a system can reason. We have developed a demonstrator (software prototype) to visualize and evaluate the outcomes of this reasoning process in different cases. In the demonstrator, we use so-called semantic triples[1] to express a given situation, which can then be used for automated reasoning. Each triple represents a basic expression in the form of Subject – Predicate – Object, for example

```
Peter – has lifestyle – vegetarian
cheese – is suitable for lifestyle – vegetarian
```

By combining these two expressions the system can infer that cheese may be acceptable for Peter. However, if Peter is flexitarian rather than vegetarian, we need additional information on for example the number of days per week that meat is acceptable. This can be done by qualifying the value 'no meat' with the number of days per week. An even more complex case could require both consumer and context data as input. For example, cheese may not be available at that point in time. In some cases, selecting a consumer attribute can even become context dependent. For example, the typical Dutch consumer would not take rice for breakfast.

In order to select relevant attributes of food items, consumers and situations for this type of reasoning, we will have to identify sources of attributes and their possible values. One source can be human behavior theory. We will consider this route in the next sub-section. Next, we will apply a more empirical approach by analyzing attributes that dietitians and food experts use in practice either explicitly or implicitly. In the third phase of this research, we have asked consumers which food attributes they would use when expressing their preferences when choosing a food item.

2.1 General behavioral model

To find the conditions that make people change their behavior, general studies on human behavior can provide relevant input. In this project we specifically consider the Behavior Change Wheel (BCW) model (2) as a potential source of selection attributes. This model summarizes a number of widely accepted concepts on behavior change. Figure 1 gives a visual impression of the Behavior Change Wheel.

[1] https://en.wikipedia.org/wiki/Semantic_triple, accessed at March 9, 2022

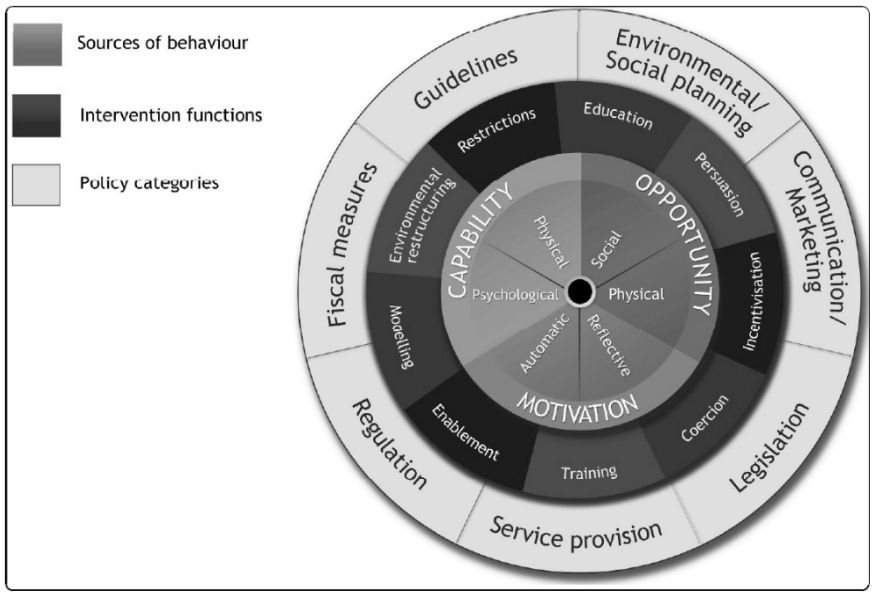

Figure 1 Behavior Change Wheel (BCW) (2)

Our first observation is that there is quite a distance between the abstract BCW and our concrete demand for attributes that link personal preferences to food items. Much of the model plays a role in how to provide a *given* personalized advice to a user, for example in an intervention tool. In particular it can help in defining the way in which the advice is being communicated. For example, the *Motivation* factor in BCW distinguishes between a *Reflective* and an *Automatic* behavior. When trying to motivate people to move to a healthier diet, the question is which of these two should set the tone of communication. Change of automated behavior requires a different approach than change based on reflection. However, we hypothesize that some elements of the model are also useful for identifying factors that are needed during the actual creation of the content of the advice.

Some first examples that may demonstrate the links between behavioral models and the knowledge required for our purpose are the following.

- *Automatic Motivation*: In the Dutch tradition we have the typical VGA-consumer, having meat-vegetable-potato for every hot meal. In this case, replacing *pork* by *chicken meat* could be acceptable, but *tofu* would be out of scope. Some new plant-based hamburgers however could be sufficiently close for the traditional consumer to be accepted.
- *Reflective Motivation*: Consumers with a preference for organic or natural products would accept *honey* or *maple syrup* as sweeteners, but not compounds such as *xylitol*.
- *Reflective Motivation*: Consumers that are highly motivated to improve their diet would except more 'unusual' alternatives than others, for example taking *humus* as an alternative spreading on their bread. *Humus* is not a traditional ingredient of the Dutch dish.
- *Social Opportunity* and *Modelling*: Consumers are influenced by the behavior of friends and family in making food choices, so alternatives suggested by them are more easily accepted.
- *Psychological Capability*: Consumers who are more educated on food products or have more cooking skills can make healthier choices.
- *Psychological Capability*: Consumers who are trained to eat products with less sugar or fat could easier get used to the taste of products that are low on these attributes.
- *Psychological Capability*: Consumers who have a Burgundian life style would make less healthy choices or choices based on taste, mouthfeel, texture.
- *Physical Capability*: If some product is not immediately available (for example sweets at home), it is easier to take an alternative that is available (e.g., fruit).
- *Physical Capability*: Consumers who have less money would make choices based on price.

In order to get from the rather abstract notions in the BCW to concrete food product attributes we have attempted to connect elements of the BCW to some attributes that we had defined in an earlier phase of our research. We tried to connect the elements in the BCW to the product attributes we have currently implemented in our demonstrator in Table 1.

Table 1 Examples of relations between BCW categories and some food attributes

	Food category	Eating Moment	Way of Application	Specific Taste	Presence of allergens
Physical capability					
Psychological capability					
Social opportunity					
Physical opportunity					
Motivation - automatic					
Motivation - reflective					
	People open to new experiences are prepared and motivated to cross category boundaries	Relevant for people with structured eating behavior	Culture specific, also related to meal moment	Personal and cultural aspect	Strict requirement

We observe that the BCW can be an inspiration for identifying food product attributes, but a comprehensive and exhaustive analysis is hard to make. We suggest that once an approach for handling food product attributes has been established via a different route, the model of Michie (2) will play a role in communicating the resulting advice to consumers in a customized app.
For a more empirical identification of attributes of food items, consumers and situations we have consulted a number of dietitians and food experts from Wageningen University & Research in The Netherlands. In addition, we have consulted the following written sources:

- Literature on food choice and motivation (3-9).
- For the attribute 'food category' we used a combination of the (sub) food groups of the Dutch Health Council (10) and the (sub) food groups of the Dutch Nutrition Centre (11). Experts appeared to consider products that are within the same category of this classification as sufficiently 'similar'.
- Own experience in projects on personalized dietary advice (12).

The evaluations with experts were very valuable in the process of defining the attributes. Sometimes assumptions made by dietitians were revealed, such as 'portions need to fit to packaged units of food items' or a rule of thumb to distribute energy intake over meal moments. In general it appeared that selecting acceptable food items is a complicated task if we go for true personalization and contextualization.

2.2 Consumer survey

After having collected an extensive set of attributes from literature, we have conducted a survey among consumers. The goal was to obtain preliminary insight in which food attributes people apply when making a food choice in a practical situation. This will give an indication of which attributes are most interesting for further research.
For this purpose we had access to a cohort of 32000 consumers using the Nature Today app[2]. This app provides topical information about nature in the user's environment. The reason for choosing this cohort for our survey is that eventually we expect some relation between people's interest in nature and their behavior as a consumer. This will make some effects more explicit than would have been the case in an arbitrary population, but introduces a bias that we deliberately accept in this phase of our research.
From the cohort 770 participants responded to a request to join our survey in the weekly email by Nature Today. Each participant had to answer the same ten questions in Dutch. Each question specified an eating moment, location and food item. It then asked for an acceptable alternative food product, to make the case more realistic and to make it easier to answer the core question: on which attributes do you base your choice for an alternative food product? We provided a list of attributes, from which one or more attributes could be selected. Figure 2 shows an example question (translated).

[2] https://www.naturetoday.com/intl/nl/home, accessed at March 9, 2022

Situation 1:

You're waiting at the station at the end of the day and you're craving a brownie. However, the brownies are sold out in the kiosk.

What would be a good alternative for you?

....

Why do you think this a suitable alternative? (multiple options possible)

- ☐ It is the same type of product
- ☐ It fits with the time of the day
- ☐ It fits with my lifestyle (e.g. vegetarian)
- ☐ It has the same taste
- ☐ It has been prepared in the same way
- ☐ It has the same temperature
- ☐ It is just as convenient to eat or drink
- ☐ It has the same price
- ☐ It is equally or more sustainable
- ☐ It is equally healthy or heathier
- ☐ It is equally unhealthy or unhealthier
- ☐ It satisfies my hunger just as well or better
- ☐ It satisfies my light appetite just as well or better
- ☐ It is just as delicious or more delicious
- ☐ It is available here
- ☐ It is suitable for this occasion
- ☐ Otherwise, namely ...

Figure 2 Example of a survey question

The full data for both study parts can be found at https://doi.org/10.4121/19298990.

3 Results

Following this approach, we obtained an extensive set of food attributes that consumers use, and an impression of the attributes that consumers use more often.

3.1 Identified attributes and values

First we list the attributes and possible values for each of them that we have collected from the sources mentioned in Section 2.1. For readability we have summarized the results here; the full list can be found at https://doi.org/10.4121/19298990. In Table 2 we first list the attributes that refer directly to food items.

Table 2 Product attributes

Attribute	Values
Belongs to food category	Vegetable Fruit Oil ...
Is suitable for eating moment	Breakfast During the morning Bread meal ...
Is applied as	Sweetener Add-on ...
Has specific taste	Sweet Savory or salty Bitter ...
Is suitable for a specific consumer	Pregnant Breast feeding
Is suitable for lifestyle	No meat No fish Vegan ...
Contains allergen	Gluten Egg Fish ...
Has consistency	Fluid Thin puree Thick puree ...
Has household unit	Teaspoon Bowl Slice ...
Has common portion size	100 gr 50 ml ...
Has been prepared as	Boiled Grilled Deep fried ...
Has to be served as	Hot Cold
Has biological source	Plant-based Animal-based
Acts as meal component for	Protein Starch Vegetable
Has main nutrient component	Protein Carbohydrate Fat
Is of brand type	A-brand House brand
Is available in season	Winter Spring Summer Autumn
Is suitable for occasion	Party Birthday party

Attribute	Values
	Kids party ...
Is suitable at location	At home On the go At work ...
Has convenience level	Low Medium High
Has price level	Low Medium High
In wheel of five (11)	Inside Outside
Is in product life cycle stage	Introduction Growth Maturity ...
Fits in geographic diet	Mediterranean West European Nord European ...
Has added sugars	Yes No
Is available at location	At home On the go At work ...
Has culinary match with	Food item

Table 3 and Table 4 list the consumer and context attributes that we have collected from the sources mentioned in Section 2.1.

Table 3 Consumer attributes

Attribute	Value
Has date of birth	dd-mm-yyyy
Has gender	Male Female Other
Has educational level	Scientific education Higher professional education Middle professional education ...
Is from social-economic class (SES)	High SES Low SES
Has family status	Single Partner no children Partner with children at home
Has maternity status	Pregnant Breast feeding
Has lifestyle	Vegetarian Pescatarian Vegan ...
Is allergic to	Gluten Egg Fish ...
Prefers price level	Low Medium High
Is from country	Netherlands Belgian Germany ...
Prefers specific taste	Sweet Savory or salty Bitter ...
Has food innovativeness (the extent to which a consumer is eager to learn about and try new food products (3))	High Medium Low
Has food neophobia (resistance to try unfamiliar food products): (4)	High Low
Has level of dietary self-efficacy (feel the ability to do something): (5)	High Low
Has food choice motive (6, 7)	Health Mood Convenience

Attribute	Value
	...
Has eating motivation (8)	Taste Habit Hunger ...
Has healthy eating strategy (9)	More vegetables More fruit More whole grain products ...

Table 4 Context attributes (at point of purchase, preparation or consumption)

Attribute	Value
Is at time	hh:mm:ss
Is at date	dd-mm-yyyy
Is at eating moment	Breakfast During the morning Bread meal ...
Is at season	Winter Spring Summer Autumn
Is at occasion	Party Birthday party Kids party ...
Is at place	At home On the go At work ...
Is in social setting	Family Household members Friends ...

As explained in Section 2, the ultimate goal is to predict which product attributes should be used to select food items that fit for a given situation and a given individual. This problem is hard to tackle in its generality, in particular if we want the process to be (partly) automated. In the simplest case a context or consumer constraint maps directly to a food item attribute value. One example was given in Section 2, for the case of a vegetarian consumer and product. In most cases, a simple one-to-one mapping is not possible. For example, with a context attribute 'Is at place = at home' there is no immediate food item attribute available to select food items. In such a case we need to add other knowledge rules, relating for example the context attribute value 'at home' to the food item attribute value 'availability = at home'. In this first phase of our research we assume that the dietitian decides which attributes to select in a specific case. Moreover, filtering occurs on the basis of similarity with the original product (that is to be replaced), as we will discuss in Section 4.3.
To show and assess potential components of digital dietary advice systems we have developed a demonstration tool (see Figure 3), as referred to above. In this demonstrator we use the product attributes to implement filters to automatically select food items from our large basic collection of products and ingredients. These filters can be switched on and off to confirm or disprove their representation of consumer preferences and were evaluated by dietitian and consumer panels. Note that the list of selected replacers in the demonstrator has been ordered in terms of health impact.
The evaluations revealed a number of issues that have to be dealt with before this approach can be put into practice, as illustrated by the following example. We found that the values of the attribute *'is for eating moment'* are difficult to get consensus on. This is due to the fact that people can have quite different habits for certain meal moments. For example, although *bread* is a typical component for a Dutch breakfast, today many people do not take bread for breakfast. Moreover, people can have a hot meal for lunch as well. To resolve this issue we have used data from the Dutch Food Consumption Survey (13) that provide *average* food consumption patterns in the Netherlands.

3.2 Consumer survey

From the 770 people that responded to the survey, 258 were male, 509 female and 3 unspecified. The age distribution is given in Table 5.

Table 5 Age distribution of respondents

Age	Number of participants
<21	0
21-40	30
41-60	193
61-80	518
>80	29

Figure 4 shows example output of the survey. From the responses we derived the following qualitative observations.

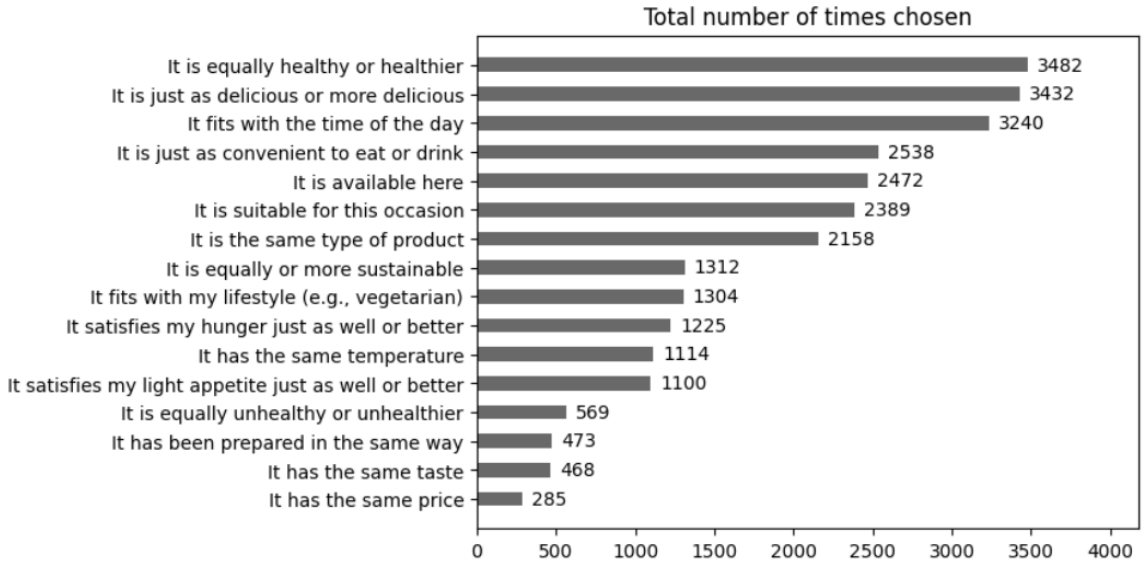

Figure 3 Example output of the survey (translated)

- 'Equally healthy or healthier' scores highest, followed by 'Equally or more delicious', whereas 'similar taste' did score low. Obviously 'equally delicious' does not necessarily mean 'similar taste'.
- 'Price' is considered to be the least important of the listed food attributes, in contrast to what is often reported. This could be due to a relatively high economic status of the respondents.
- We do not see much difference between the answers of the age groups 41-60 and 61-80, which together cover 92% of the respondents.
- The attribute 'equally or more sustainable' receives an average importance score. The Nature Today cohort can be expected to be more nature minded than the average Dutch citizen and therefore more than average interested in sustainability.
- In the situations with meal moments (breakfast, lunch and dinner), 'health' is a bit more important than in the situations with in-between meals (snack moments).
- In situations with dinner as eating moment, 'health' is considered more important than at breakfast and lunch.
- In situations with meal moments, the 'preparation method' is much more important than in the situations with in-between meals (snack) moments. Probably most snacks require less preparation.
- 'At home' replacers are expected to be similar to the original ingredient, 'out of home' other substitutes are accepted.

4 Discussion

At a more fundamental level we have identified the following issues that emerged when applying the above attributes in practical cases.

4.1 Food item classifications

The attribute 'food category' seems to be the most obvious attribute for selecting similar food items. For example, it is much more probable that 'lettuce' is accepted as an alternative for 'chicory', which are both in the category 'vegetable', than by 'green beans', which are in the category 'legumes'.
Classification however is a delicate issue, in particular in modelling food products and ingredients as these are produced from natural products. In principle every single product on the shelf is unique and has its own characteristics, in particular if it is a fresh product. In practice, many competing classifications are proposed, which can cause confusion. For example, 'wholegrain bread' can be classified either as 'bread' or as 'wholegrain product'. In those cases it is advised to replace classifications by specialized properties; in this case we could say `wholegrain bread – is produced from – wholegrain cereals`. In that way `wholegrain bread – is a kind of – bread` can still be maintained as a static classification. In practice, different sources have different arguments for classifications. For example, the food item categories in FoodEx2 (14) are basically grounded in food safety considerations, whereas the food groups used by the Netherlands Nutrition Centre are based on nutritional values.
To define food items and categories in software, we need a machine readable format. SKOS (Simple Knowledge Organization System)[3] is a formal language to express – among others- hierarchical relations between things (taxonomies) in *controlled vocabularies*. SKOS allows weakly defined 'broader' and 'narrower' relations which makes it possible to handle taxonomies more loosely than would be possible in more formal languages, such as RDFS/OWL[4].

4.2 Attribute values

In addition to defining the set of attributes for food products, consumers and context, it is a challenge to define which values these attributes can have. Of course it is not possible to determine a universal set of allowed values that works in all possible cases, several choices will have to be made depending on the considered applications.
For example, different attributes may be needed for different levels of specificity. For example, 'location' can be a region or at home. Another example is 'consistency', for which the values 'solid', semi-solid' and 'fluid' suffice for most households, but a more detailed description is needed for people with swallowing disorders (15). An advisory app that is more specific can be more effective (16), but also requires more (private) information.
Another challenge is that in practice there will be many products for which no attribute values are known (initially). In principle we can simply leave the value empty, but this would not show why this value is missing. More informative values for such situations are 'unknown', 'not applicable', 'any of the possible values', 'other value'. For example, in terms of allergens it is important to state that the presence of peanuts in a product is 'unknown' or 'not present'.

[3] https://en.wikipedia.org/wiki/Simple_Knowledge_Organization_System, accessed at March 9, 2022
[4] https://www.w3.org/OWL/, accessed at March 9, 2022

A major challenge is that product attribute values will have to be determined for all food items. Manually assigning attribute values is not feasible, given the huge set of possible food product and ingredients. Methods from text mining and machine learning can assist in determining such values. For example, we have been able to predict taste values for many products from their nutritional values and other attributes. The large amount of recipes available on the web can be a major source for such self-learning methods. Another option is to make use of crowd sourced input.

4.3 Using attributes to select 'similar' products

The attribute values that describe a specific person and a specific context can be asked explicitly from this person, for example by specifying a personal profile and depicting his or her situation. This would allow an dietary advice tool to suggest alternatives that fit with the user's preferences and with the current situation, without the need to know their habitual food intake. But these personal preferences can also be inferred from the current or average food intake of that person. As a first step towards automated generation of acceptable alternative food items, in our demonstrator we use the observed intake as an implicit and partial representation of the consumer's dietary preferences at a specific eating moments.
The product attributes then allow us to propose relevant replacers, based on the *similarity* between the attribute values of the original products and the attribute values of potential replacers, together with the health impact of the replacers on the overall diet. For example, if currently 'white pasta' is eaten, this can be replaced by 'wholegrain pasta' as it is occurring in the same category and both are eaten by the consumer at a 'hot meal'. The similarity can be based on the intake of the individual consumer, or on the eating habit of a coherent group of consumers (a 'persona'). For example, the Dutch consumer eats 'bread' with a 'bread topping' at 'breakfast' and at 'bread meal'. In this way some aspects of the consumer profile can be derived from her food intake. But, to be absolutely sure this has to be confirmed by the consumer before applying this as an absolute filter to all the replacers. For example, a consumer could be a vegetarian or might just not have been eating meat for some time.
We do realize however that suggesting 'similar' products cannot be the only way to stimulate dietary changes. Advice only based on similarity with current habits would not stimulate consumers to move outside their comfort zone, for example when replacing or abandoning unhealthy snacks or sweets.

4.4 Applying the attributes: filtering and sorting food items

Once the attributes have been defined, their values for all possible products have been found and the knowledge rules for inferring specific cases have been established, the result has to be presented to the user. There are two possibilities to use the inferred information. The first option is to use the product values as filters, i.e., to select or eliminate products from the overall list. This is what we currently do in our demonstrator (see Figure 3, in which the filtered values also have been ordered for their health impact). The second option is to use them for *ranking*, i.e., to sort them in terms of acceptability. This requires assigning a level of acceptability (see Figure 3, the numbers between brackets behind the alternatives) for each attribute value, which would have to be combined with the health impact of a product.

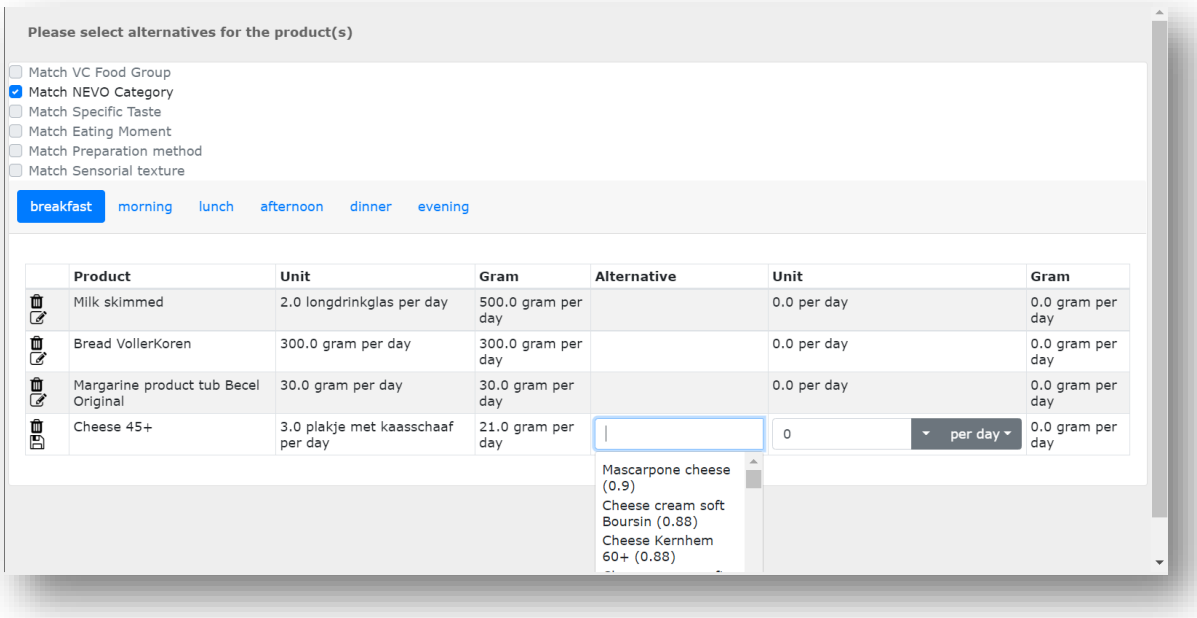

Figure 4 Impression of a test setup for automated food product selection

It is clear that selecting alternative food items based on one attribute only will often not give an acceptable result. For example, to products can be similar in taste (for example 'black coffee' and 'pilsner beer') but not be accepted as a replacer (for example at 'breakfast'). Moreover, the possible values of one food item attribute may be dependent on the value selected for another attribute. For example, a 'common portion size' would not fit with any 'household unit'. Which attributes to combine may even be different between individual consumers. Creating optimal combinations of attributes in specific cases is still a challenging task.

4.5 Priorities in food attributes

We already mentioned that the population of our cohort is possibly slightly biased in the sense that the respondents may be more conscious and outspoken about the importance of sustainability and even health impact of food than a more representative selection. However, the results do give some directions on which questions to ask next.

- First, how can we relate taste and other aspects, which can be measured more or less objectively, to liking and wanting? Creating algorithms that can predict liking and wanting is quite a challenge and will have to build on existing literature in this field (e.g., (17, 18)). Possibly collecting more consumer data along these lines and machine learning analysis can give additional input.
- Since 'eating moment' seems to be an important determinant, more data is needed on which food products are eaten at which moment.
- Also 'convenience' seems to be relevant in making food choices. Therefore this concept needs to be further formalized based on existing expertise in this field, and related to individual food items.
- The food choice is a complex decision making process, which requires multi-criteria decision making algorithms. Although some steps have been made here to determine the optimal health impact of food items (nutritional value), inclusion of personal preferences is crucial for creating effective digital dietary advice systems.

5 Conclusion

We have outlined an approach to infer acceptable food items from an individual's preferences and context. Such a set of preferred products can then be ranked for their contribution to a healthy (or possibly sustainable) diet. The idea is that in this way consumers are able to gradually and sustainably improve their overall dietary pattern as the proposed alternatives fit with their personal life style and habits.
We find that the Behavior Change Wheel can be used as a source of inspiration, but does not give direct input for selecting concrete attributes. We expect BCW to become more relevant when decisions about the way of communication are to be made.
By combining several sources we have established a set of attributes for food items, consumers and situations related to food consumption. These attributes can in principle be used to identify 'acceptable' products for each individual person and situation. The attributes 'healthy' and 'delicious' are scoring high in the population we studied. 'Eating moment' seems to be an significant determinant for other food item attributes. Although fully automatic generation of food alternatives is not yet possible, dietitians and life style coaches can benefit from the data that is already available. A number of web services is currently being developed to access the data programmatically, for example in dietary apps.
The next step in our research is to select the most promising attributes, for which we also can determine the required product attributes values in a scalable way. Which dependencies do they have and which inference rules are needed? How to combine several attributes in filtering or sorting acceptable food items? We will use our demonstrator to evaluate the gained added value with dietitians and consumer behavior experts.

Acknowledgements

This work was supported by the Dutch Ministry of Agriculture, Nature and Food Quality in the Wageningen University & Research research programs Data Driven & High Tech and Healthy and Safe Food Systems. They were not involved in this research nor in the preparation of this article. The authors would like to thank Sandra van der Haar, Meeke Ummels and Arnold van Vliet for their contributions to this study.

References

1. Adams SH, Anthony JC, Carvajal R, Chae L, Khoo CSH, Latulippe ME, et al. Perspective: Guiding Principles for the Implementation of Personalized Nutrition Approaches That Benefit Health and Function. Adv Nutr. 2020;11(1):25-34.
2. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6(42):42.
3. Goldsmith RE, Hofacker CF. Measuring consumer innovativeness. Journal of the academy of marketing science. 1991;19(3):209-21.
4. Eertmans A, Victoir A, Vansant G, Van den Bergh O. Food-related personality traits, food choice motives and food intake: Mediator and moderator relationships. Food Quality and Preference. 2005;16(8):714-26.
5. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev. 1977;84(2):191-215.
6. Steptoe A, Pollard TM, Wardle J. Development of a measure of the motives underlying the selection of food: the food choice questionnaire. Appetite. 1995;25(3):267-84.
7. Onwezen MC, Reinders MJ, Verain MCD, Snoek HM. The development of a single-item Food Choice Questionnaire. Food Quality and Preference. 2019;71:34-45.
8. Renner B, Sproesser G, Strohbach S, Schupp HT. Why we eat what we eat. The Eating Motivation Survey (TEMS). Appetite. 2012;59(1):117-28.
9. Verain MC, Raaijmakers I, M.J. R. Identification of healthy eating strategies: predictors and consumer differrences. 2018.
10. Gezondheidsraad. Richtlijnen goede voeding 2015. Den Haag: Gezondheidsraad; 2015. Report No.: 2015/24.
11. Voedingscentrum. Richtlijnen Schijf van Vijf. Stichting Voedingscentrum Nederland; 2020.
12. Rijnaarts I, de Roos NM, Wang T, Zoetendal EG, Top J, Timmer M, et al. Increasing dietary fibre intake in healthy adults using personalised dietary advice compared with general advice: a single-blind randomised controlled trial. Public Health Nutr. 2021;24(5):1117-28.
13. Rossum CTMv, Buurma-Rethans EJM, Dinnissen CS, Beukers MH, Dekkers ALM, Ocké MC. The diet of the Dutch. National Institute for Public Health and the Environment; 2020.
14. EFSA. The food classification and description system FoodEx2 (revision 2). European Food Safety Authority; 2015.
15. Cichero JA, Lam P, Steele CM, Hanson B, Chen J, Dantas RO, et al. Development of International Terminology and Definitions for Texture-Modified Foods and Thickened Fluids Used in Dysphagia Management: The IDDSI Framework. Dysphagia. 2017;32(2):293-314.
16. de Roos B, Brennan L. Personalised Interventions-A Precision Approach for the Next Generation of Dietary Intervention Studies. Nutrients. 2017;9(8).
17. Berridge KC. Food reward: Brain substrates of wanting and liking. Neuroscience & Biobehavioral Reviews. 1996;20(1):1-25.
18. Havermans RC, Janssen T, Giesen JC, Roefs A, Jansen A. Food liking, food wanting, and sensory-specific satiety. Appetite. 2009;52(1):222-5.

To explore the potential of nature to improve the quality of life

Wageningen Food & Biobased Research
Bornse Weilanden 9
6708 WG Wageningen
The Netherlands
www.wur.eu/wfbr
E info.wfbr@wur.nl

Report 2375

Public

The mission of Wageningen University and Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 10,000 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.