Perspectives on personalised food

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A B S T R A C T

Background: Personalisation of foods opens for improving individuals' quality of life. In the personalised food approach, the focus of research is food, its components and the possibilities of different processes throughout the food value chain to impact on individuals and their needs.
Scope and approach: In this paper, we will provide an overview of how research from a personalised food perspective can benefit consumers that require special food offerings. The paper is structured along the food chain addressing the following topics: i) Food raw material and components, ii) Food processing and culinary aspects, iii) Food digestion and microbiota, iv) Food perception.
Key findings and conclusions: The paper highlights how food and its composition influence personal requirements, and how processing of the foods can contribute to optimised products for consumer groups. Furthermore, much attention has been accorded how digestion and microbiota are sensitive to food consumed and how this vary with consumer group. Finally, consumers' perceptions and preferences play an important part in how foods are presented and chosen. More research is needed to utilise the possibilities of personalising foods to improve life for consumers with different needs.

1. Introduction

Humans are complex beings with respect to dietary needs and preferences at both individual and group or population levels. Personalisation of food is not a new idea, and humans have personalised foods and diets for as long as we have existed. An example is how foods, such as herbs, roots or other products, have been used in hope of remedying specific health issues. Other reasons for personalising food intake can be of social, cultural or physical origin. Added to this, foods can be personalised to fit preference patterns or differentiated sensory sensitivities (Bartoshuk, Fast, & Snyder, 2005). Whatever the reasons for personalising food intake, food go through a complex process throughout the food chain from production to digestion (King et al., 2017).

In the literature, investigating individual dietary needs have mainly been done in the context of personalised nutrition. Following the Human Genome Project lasting from 1989 to 2003 (http://www.ornl.gov/hgmis), a whole new vista of possibilities was opened in medicine and nutrition for tailoring measures to the individual (Celis-Morales et al., 2014; FOOD4ME, 2015). In this setting, personalised nutrition

was coined as the solution to consumers' needs for health promoting diets and dietary advice (Ordovas, Ferguson, Shyong Tai, & Mathers, 2018). However, to make personalised nutrition work for the individual, relevant and personalised food products must be made available. Therefore, knowledge is needed about which characteristics of nutrients, food products, production processes and consumers themselves that can impact personalisation.

In an everyday context, mass production of personalised foods for individuals or small groups of people is not a feasible undertaking. Thus, developing personalised food products is both time- and labour-intensive and requires multidisciplinary and in-depth knowledge in a wide range of food-related fields, as this paper exemplifies. Approaching the personalised concept from a food point of view provides an additional aspect to personalised nutrition. In the personalised food approach, the focus of research is food, its components and the possibilities of different foods throughout the value chain to impact individuals and their needs (see Fig. 1) (King et al., 2017).

In this paper, we will provide an overview of how research from a personalised food perspective can benefit people with special needs. The paper is structured along the food chain addressing the following

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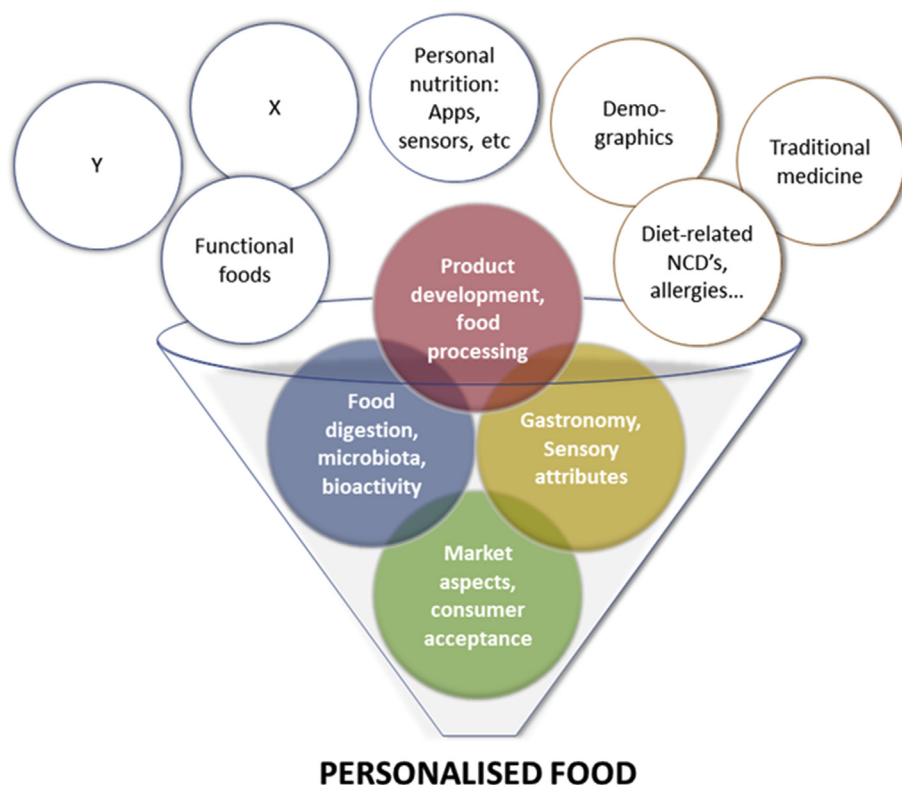
Fig. 1. The personalised food perspective. Topics that are covered in this paper in the circles highlighted in colour within the funnel. Associated topics in white circles, including X and Y signifying other subjects of relevance not mentioned. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

topics:

- Food raw materials and components
- Food processing and culinary aspects
- Food digestion and the microbiota
- Food perception

2. Food raw materials and components

Food is the vehicle of essential macro- and micronutrients to humans, and raw materials can be treated and used in various ways to address personal dietary needs. Individual needs vary, and recommended intakes can thus be optimised based on a person's biological characteristics and specific goals. Personalisation of foods requires knowledge of foods' nutrient composition, and in the following sections, the impact of macronutrients (protein, fat and carbohydrates) is addressed.

2.1. Protein

Proteins consist of amino acids, nine of which are classified as essential, in a polypeptide chain. Proteins attain their nutritional value when digested into single amino acids or small peptides in the small intestine.

Digestibility and uptake in the body may be influenced by the way proteins are processed and incorporated into the food matrix, which must be taken into account when developing foods for personalisation. Adequate intake of easily digestible protein is particularly important for certain groups and individuals, e.g. elderly with risk of declines in muscle mass and strength, and individuals suffering from malnourishment or severe illness or injury. More knowledge about inter-individual variability in response to protein foods is needed, not only with respect to digestibility and uptake, but also regarding bioactive potential. Examples are peptides impacting muscle mass, satiety, blood pressure, cholesterol reduction and inflammation (Sanchez, 2017).

Meat and fish are important sources of high-quality protein (Bohrer,

2017). Due to climate and health concerns, there is a growing trend to partly or fully exchange meat products with non-meat protein foods. According to recent dietary guidelines from the US Department of Health and Human Services 2016, nutrients from meat and fish sources can be successfully exchanged with plant foods, such as legumes, soy, nuts, seeds, and whole grain products. However, it may be necessary to mix different plant-based proteins to ensure adequate intakes of essential amino acids. The green shift towards new and more sustainable protein sources warrants further investigation of the role of plant proteins in nutrition and health.

2.2. Fat

Fat is an important part of a healthy diet, providing not only energy but also essential fatty acids, fat-soluble vitamins, phospholipids and plant sterols. Different fatty acids may differ greatly in their health impact. Dietary recommendations have mainly focused on decreasing total fat intake, in particular saturated fat. Reduction in the risk of cardiovascular disease (CVD) is obtained primarily by replacing saturated fat with polyunsaturated fat, reducing serum cholesterol. The inter-individual variability in response to changes in dietary fatty acid composition is relatively high, as is the response to plant sterols commonly added to cholesterol-reducing foods (Heggen et al., 2010; Muller, Kirkhus, & Pedersen, 2001). Non-responders to plant sterols exist due to genetic variations, indicating that genetic tests may help healthcare professionals when recommending dietary strategies (Jones, 2015).

Few nutrients have been studied as thoroughly as omega-3 fatty acids. In particular, the long-chain n-3 polyunsaturated fatty acids present in fish and other marine sources seem to have several beneficial effects, e.g. prevention of CVD, cancer and inflammation as well as improving eye, brain and mental health. There has, however, been a great deal of controversy about the potential role of n-3 intake in human health. Many factors may contribute to the observed variability in efficacy and inconsistency between studies, such as genetic variants, ethnicity and gender (Hooper, De Souto Barreto, Pahor, Weiner, &

Vellas, 2018; Lohner, Fekete, Marosvolgyi, & Decsi, 2013; Patel, Tracey, Hughes, & Lip, 2010). Further research is warranted in this field to gain more knowledge about inter-individual responses to fats.

2.3. Carbohydrates

Carbohydrates are a diverse group of molecules and an important source of energy. Factors affecting digestibility, absorption and energy metabolism are the degree of polymerisation (mono-, di-, oligo- and polysaccharides) and structure. The food matrix is another important factor, exemplified with starch, the most common carbohydrate in the human diet. Intake of starch-rich food can cause fast or slow release of glucose dependent on food matrix, which protects starch from digestion. When starch is not digested, it can be defined as resistant starch. Hence, a growing trend is designing foods, meals or processes that can delay glucose release, or increase the amount of resistant starch.

Other polysaccharides, such as non-starch polysaccharides or fibre, are plant carbohydrates that are not digestible by human enzymes. Whole grains contain high amounts of dietary fibre, and consumption of dietary fibre is positively linked to all kinds of health effects, including prevention of cancer, CVD and obesity. This is related to fibre properties, for instance solubility. Soluble fibres such as beta-glucan or pectin slow down digestion and reduce postprandial glycaemia and cholesterol absorption. Cellulose and other insoluble fibres absorb water in the intestines, thereby softening and bulking stool, in turn preventing constipation. Furthermore, the energy in dietary fibres and resistant starches are important fuels for the gut microbiota affecting host physiology and health to a great extent (Makki, Deehan, Walter, & Backhed, 2018). Both fibre composition and structure differences greatly impact their degree of fermentability by gut microbiota, and thus, how they affect the gut microbiota composition, metabolic activity and host regulation. The carbohydrate diversity and variability make them highly attractive targets for food personalisation, especially in affecting nutrient absorption and gut microbiota modification.

2.4. Protein-rich residual materials

The protein-rich residuals resulting from industrial processing of animals and marine organisms have the possibility to be sustainable protein sources, with excellent nutritional value (Aspevik et al., 2017). By strict regulations, the residuals are divided into those that can be used for human consumption, and by-products, which cannot.

There is a growing industry based on utilization of protein-digesting enzymes, proteases. These perform protein hydrolysis to extract proteins in the form of peptides from these residual materials. This is regarded as a mild processing method resulting in high protein yields, without compromising the nutritional value of the products, as happens during chemical hydrolysis.

An interesting feature of enzymatic protein hydrolysis is that the resulting peptides have shown improved nutritional and functional properties as compared to the start materials. Smaller peptides have shown to be easily absorbed into the intestine. Hydrolysates with a high amount of low-molecular weight peptides might therefore be beneficial for specialised nutritional formulas. Examples are use in diets for older adults in need of extra protein to maintain body weight or in formulas for infants with allergies (Clemente, 2000; Frøkjaer, 1994; Neklyudov, Ivankin, & Berdutina, 2000).

A sub-segment of the peptide products are bioactive peptides, short peptide chains showing hormone- or drug-like activity towards numerous disease-related molecules in the human body (Fitzgerald & Murray, 2006). There are many reports on bioactive peptides derived from protein hydrolysis, with a focus on blood pressure lowering, blood sugar regulation, and antimicrobial and antioxidant activities (Lafarga & Hayes, 2016; Zamora-Sillero, Gharsallaoui, & Prentice, 2018).

3. Food processing and culinary aspects

Food processing has a key role in the development of personalised foods, as it allows modifying the food raw materials and ingredients and creation of specific functional, nutritional, and sensory attributes (Augustin et al., 2016; Weaver et al., 2014). Processing methods can also extend the shelf life of food products, which make the products safe for various user groups, for example, those who are immunocompromised (e.g. older adults, hospitalised and diseased) and need food products with a high safety margin.

3.1. Texture modification

An important product segment in relation to processing is texture modified food. As the texture modification process influences many food properties, such as appearance, taste and smell, texture modification makes it necessary to adjust several food parameters using different processing methods.

Texture modified foods is a term that refers to foods with soft textures and/or reduced particle size as well as thickened liquids (drinks). Texture modification is applied to adapt foods for consumer groups with specific needs, ranging from babies to people suffering from complications or physical limitations after diagnoses such as stoke, paralysis, injuries in the head/oesophagus/neck and mouth and for many older adults (Wirth et al., 2016). However, the nutritional, sensory and textural needs may differ widely within the group of consumers requiring texture modified foods. Texture modification of food may limit the foods' attractiveness, and the amount of research conducted to elucidate consumer acceptance of texture modified foods is scarce. Food structure and textural properties may also influence consumers perception and expectations of satiety, satiation and ultimately food intake (Nguyen, Wahlgren, Almli, & Varela, 2017). If well accepted products are created for easier oral processing through modified structure, it could be utilised for personalisation, creating foods with less satiating characteristics, aimed to increase intake (e.g. older adults with undernutrition) or to create more satiating textures for consumers aiming to reduce caloric intake and thus lose weight.

Both conventional and innovative processing methods are used to personalise foods with physical and biochemical approaches (Barba, Terefe, Buckow, Knorr, & Orlien, 2015; Eom, Lee, Chun, Kim, & Park, 2015; Nakatsu et al., 2014; Puertolas, Luengo, Alvarez, & Raso, 2012). There are three main technological alternatives to engineer soft texture modified foods for special consumer groups: i) conventional processes that cause softening of traditional meals (e.g. meats, fruits and vegetables); ii) techniques to produce biopolymer particles and microgels, mostly used to modify the rheology of liquids for safe swallowing or as carriers; and iii) new emerging structuring technologies (Aguilera & Park, 2016). Process technologies, such as mincing, pureeing and thickening (liquids), can be used to achieve desirable soft texture (Cichero, 2016). Although to achieve the desired texture and increase functionality of food, addition of a binding agent or additive is often required (e.g. hydrocolloids like polysaccharides). The interactions between the proteins present in food and added hydrocolloids can give rise to different textures (van Nieuwenhuyzen, Budnik, Meier, & Popper, 2006).

High pressure processing, enzymatic treatments, pulsed electric fields and sonication present technologies for texture modified foods to retain the overall appearance and flavour of whole pieces while softening their structure (e.g. they break down easily in the mouth). Proper control of process variables allows preservation of food colour and flavour while tuning their soft texture to different extents (Table 1).

High pressure homogenization (HPH) is a widely used process in the food industry (Harte, 2016) and a well-known technique to produce stable oil-in-water emulsions. At high pressures, disruption and restructuring of the food matrix take place, and nutrients are released from the matrix, making them more accessible for absorption in the

Table 1
Technologies used in processing food and meals for texture modification for target consumer groups (after/modified from Aguilera & Park, 2016).

Technology	Foods	Principle/claim	Key references
High pressure processing	Many foods (meat, salads, ready meals, etc.)	Soften foods, retain flavour and nutrients, may improve bioavailability of bioactive compounds	Barba et al. (2015) Chen et al. (2018)
High pressure homogenization	Soups, gels and meat	Reduce particle size in colloidal foods. Create emulsions. Produce water-soluble myofibrillar proteins.	Chen et al. (2018)
Enzymatic treatments	Beef, chicken, and other foods	Impregnation of foods with enzymes that breakdown cell wall components and/or structural tissues, leading to bland textures	Eom et al. (2015) Kim and Joo (2020)
Heat treatment	Beef, chicken and fish	Improve meat texture and smooth down meat oral processing	Vandenberghe-Descamps, Labouré, Septier, Feron, & Sulmont-Rossé (2018)
Pulsed electric fields	Several cellular foods	Tissue softening in fruits and vegetables is induced by cell membrane electroporation	Puertolas et al. (2012) Faridnia, Burritt, Bremer, and Oey (2015) Parniakov, Bals, Lebovka, and Vorobiev (2016)
Freeze-thawing infusion	Bamboo shoots, roots, fish, mushrooms, etc,	Impregnation of substances (e.g. enzymes) into foods combined with slow freezing and vacuum. Softens the food while keeping flavour	Parniakov et al. (2016) Nakatsu, Kohyama, et al. (2014) Eom et al. (2018)

small intestine. As an example, combining heating and HPH of tomato enhances the bioaccessibility of lycopene (Kirkhus et al., 2019; Salvia-Trujillo & McClements, 2016; van Het Hof, West, Weststrate, & Hautvast, 2000). HPH emulsions are suitable for introduction into several food products, adding nutritional value, as well as colour and taste, to final products.

Texture modification combined with mechanical and biochemical alterations have opened for development of functional foods, as one aspect of personalised foods, and increased peer reviewed publications with 350% since 2006 (Birch & Bonwick, 2019; Granato et al., 2020). Innovative technologies presented in Table 1 has positive impact from a functional point of view by better preservation of nutrients. In addition, nanoparticles or microparticles containing bioactive compounds or essential minerals can be effective solutions to administer functional components (Amoah, Cairncross, Sturny, & Rush, 2019; Wang, Xu, Yue, Chen, & Wang, 2019).

The alterations in structure of food components during processing can represent a challenge but can also be used advantageous to produce specific properties. Possible structural modifications appear in proteins, such as unfolding, aggregation, cross-linking between the ingredients and chemical modifications like oxidation and glycosylation (Lepski & Brockmeyer, 2013). Resultant conformational changes can directly influence allergenicity by disrupting conformational or linear epitopes. Conformational epitopes can be exposed or hidden by unfolding or aggregation of proteins (Rahaman, Vasiljevic, & Ramchandran, 2015), respectively, whereas linear epitopes can be affected by acidic or enzymatic hydrolysis (Kasera, Singh, Lavasa, Prasad, & Arora, 2015). Processing-induced physico-chemical changes in food proteins can influence allergenicity by affecting gastrointestinal digestibility, absorbance kinetics through mucosa, and their presentation to the immune system. The degree of structural alteration and allergenicity depends on the processing method used, extent and exposure time, and presence of other ingredients, such as salt, sugar, etc. (Cuadrado et al., 2018; Verma, Kumar, Das, & Dwivedi, 2012).

3.2. Culinary aspects

Earlier, the culinary aspects of personalised food were areas given lower priority than the more technical aspects of the food (e.g. the concentration of allergens), but consumers now expect higher sensory quality in personalised products and functional foods, and the palatability of the products is an important factor for consumer satisfaction (Siró, Kápolna, Kápolna, & Lugasi, 2008; Verbeke, 2006). Most food ingredients have several properties in a product, such as both textural and flavour properties, which makes it challenging to replace specific ingredients. An example is table sugar, which imparts sweet taste in food, but also has important bulking and textural qualities, which may

make it challenging to replace by other ingredients. Several types of modifications are therefore often necessary in order to optimise different sensory parameters in customised food. Bridging the gap between science and practical culinary knowledge may result in personalised products where physical properties are combined with superior sensory qualities. Optimised culinary properties and appetising products are especially important for people with health problems, as illness, for one, may reduce appetite.

4. Food digestion and the gut microbiota

4.1. Digestion and nutrient bioaccessibility

Digestion is the mechanical and chemical breakdown of food into smaller components that are more easily absorbed into the blood stream. Knowledge about the bioaccessibility of a nutrient, defined as the fraction released from the matrix in the gastrointestinal tract, is of particular importance as nutrients entrapped in the food structure cannot be absorbed. Processing and food characteristics, such as microstructure, may influence the digestion kinetics and bioaccessibility of both macro- and micronutrients (Gibson, 2007; Hiolle et al., 2020). Also, interactions between food components that take place during digestion may interfere with nutrient digestibility and absorption, and this should be taken into account when developing foods for personalised nutrition.

Passage through the gastrointestinal tract (i.e. mouth, stomach, small intestine and large intestine) is the least understood of all food processes. One reason may be that it is not easily available for analysis. Thus, *in vitro* studies have, to a large extent, been used to gain more knowledge about the digestive process, including nutrient bioaccessibility. As compared with human studies and *in vivo* animal models, *in vitro* digestion models have the advantage of being more rapid, less labour intensive and having less ethical restrictions. Recently, a harmonised *in vitro* model simulating adult human digestion was developed in the EU COST-action INFOGEST (Brodkorb et al., 2019). The model has been extended to include *in vitro* digestion models simulating the digestive process in specific groups, such as older adults and infants, and may as well be used to simulate physiological conditions related to various disorders in the human gastrointestinal tract, such as cystic fibrosis, cirrhosis, pancreatitis, etc. (Shani-Levi et al., 2017). Hence, *in vitro* digestion models are becoming a valuable tool in the research on personalisation of food. The models can be used to investigate many different issues, e.g. how processing affects nutrient bioaccessibility (Kirkhus et al., 2019; Lorieau et al., 2018), interactions between meal components (Aarak et al., 2013) and formation of carcinogenic compounds in the intestine (Steppeler, Haugen, Rodbotten, & Kirkhus, 2016). Digestion models are particularly suited for investigating

nutrient bioaccessibility, and when coupled to cell culture systems (e.g. Caco-2 epithelial cells), cellular uptake and brush border enzyme activity can be studied as well.

Ageing is associated with changes in gut functions, such as less secretion of digestive fluids and enzymes. It is not well-known how these changes influence food digestion. In particular there is a need to understand how various protein sources are digested in the ageing gastrointestinal tract, as older adults are recommended to increase their protein intake in order to prevent sarcopenia and disability. Proteins are however considered effective satiating food components. The satiety signalling of protein digestion products (peptides) in the gut is not well understood, but both protein source and processing seem to be of importance (Santos-Hernandez, Miralles, Amigo, & Recio, 2018). The satiating effect may be a challenge when designing protein-rich foods for older people at risk of undernutrition. Difficulties with chewing and swallowing (oral processing) may also influence digestion capacity. When foods are poorly digested, the absorption of nutrients in the small intestine is reduced, whereas more nutrients reach the large intestine where it may affect the microbiota.

4.2. Gut microbiota

The highly populated microbial community in the large intestine (~100 trillion), ferments food components not digested and absorbed in the small intestine. It is now established that the gut microbiota also has important functional potential for the host. A complex interplay exists between the microbes and the host, modulating biological processes essential for health (e.g. maturation of the immune system and regulation of glucose and lipid metabolism). When this interplay is disrupted by impaired balance of the gut microbiota, or dysbiosis, it can lead to the development of various chronic diseases with an underlying inflammatory condition, such as inflammatory bowel disease, obesity, allergic disorders, CVD and colorectal cancer. However, what defines a healthy gut microbiota is not clearly defined yet and complicated by high inter-individual differences in microbiota composition.

Diet plays a fundamental role in shaping the composition of the gut microbiota. Carbohydrates are the preferential energy source for the gut microbiota, which they ferment to beneficial short chain fatty acids (SCFAs) important for gut tissue integrity and host metabolic regulation. A Western diet with low intake of microbiota-accessible carbohydrates (i.e. dietary fibres), and increased amounts of fat, simple sugars and protein, may reduce the microbial diversity and lead to disappearance of specific bacterial species in the gut (Sonnenburg et al., 2016). Although less is known about protein fermentation in the gut and its consequences on host health and metabolism, it results in lower production of SCFAs and more of metabolites (i.e. hydrogen sulphide, ammonia and phenols) with potential inflammatory properties, thus increasing the risk of colitis and colorectal cancer. High intake of saturated fat is also associated with a higher risk of developing colorectal cancer and suggested to be due to increased bile acid secretion into the gastrointestinal tract with increased microbial formation of secondary bile acids that are inflammatory and potentially carcinogenic.

Designing food towards a balanced feeding of the gut microbiota and their metabolites is a strategy to enhance human health. The types of carbohydrates, proteins and fats need to be taken into account, as well as proper balancing of the different macromolecules. A diet that contains different sources of dietary fibre, such as whole cereal grains and vegetables, will feed different types of microbial species. The soluble fibres are in general readily fermented into SCFAs, while the insoluble fibres act as bulking agents and can delay or inhibit proteolytic fermentation and formation of toxic compounds. Dietary proteins from animal sources can also increase the number of bile resistant microbes in the gut, as an increased amount of saturated fat follows. The gut microbiota thrive on what is not bioavailable for the human body, thus the food matrix and food processing methods that affect nutrient bioaccessibility are likely to have implications for the gut microbiota

and composition (Moen et al., 2016), likewise, impaired digestion, as seen in older people.

The magnitude of impact of dietary intervention on the gut microbiota varies widely among individuals. High inter-individual variation in microbiota composition and prior dietary practices are factors that can determine an individual's response to a dietary intervention. This has been addressed in a study by Zeevi et al. (2015), where individuals' microbiota profile was used as a biomarker for responsiveness to diet. Interestingly, identical meals induced interpersonal responses of postprandial glucose, which when linked to individual microbiota profile, could be incorporated into a machine-learning program for accurately predicting the individual human response to meals. This form of data integration of microbiota and health parameters is a promising future approach within the field of personalised food for enhanced health.

5. Food perception

In addition to the technical and biological aspects of personalisation of foods, the individual's needs and perceptions play a major role in how the foods are embraced and consumed.

5.1. Sensory perception and personalisation

Blakeslee and Fox (1932) first described the "different taste worlds" produced by genetic variation with the discovery of supertasters, individuals who live in a particularly intense taste world. Depending on their responses to 6-*n*-propylthiouracil (PROP, a bitter compound), people can be classified into supertasters, medium-tasters and non-tasters. Supertasters perceive more intense tastes, feel more burn from pungent foods and are more sensitive to creaminess (Bartoshuk, 2000). Moreover, individual differences in taste sensitivity are determinants of vegetable preference and intake, with implications for healthy eating (Shen, Kennedy, & Methven, 2016). Genetics can also determine the ability to perceive other stimuli, such as some odours, fat taste, viscosity or pungency.

Each person develops a unique set of food preferences based on their food experiences. Inborn preferences are determined by evolution for survival (Birch, 1999). Preferences are later shaped by feeding practices (Benton, 2004; Mennella & Beauchamp, 2002; Ventura & Mennella, 2011), food exposure (Wardle, Herrera, Cooke, & Gibson, 2003) and developmental stages. Along the lifespan, preferences are dynamic and forged by culture, physical and psychological traits and social interactions (Köster, 2009) as well as food experience and life situation. In old age, sensory losses will accompany life course transitions for some consumers, possibly changing completely the way they perceive (Doets & Kremer, 2016).

5.2. Food choice and personalisation

Food choices are complex behaviours determined by the interactions of many factors (Köster, 2009). For example, the consumption of organics is linked to ethical values or attitudes towards health or sustainability (Honkanen, Verplanken, & Olsen, 2006). Decision-making styles and motivations as well as personality determine inter-individual differences in consumer behaviour; people differ not only in how they make decisions but also on how they respond to the uncertainty about those decisions (Kanai & Rees, 2011; Washburn, Smith, & Taglialatela, 2005). A review on sustainable food consumption highlighted that personality characteristics, food-related lifestyles and behaviour were efficient in differentiating consumer segments regarding sustainability, and these groups differed on the importance they gave to price and health (Verain et al., 2012). Personality factors could be predictors of preferences; for instance, frequency of chili consumption has been found to be positively associated with personality variables such as "sensation seeking" and "sensitivity to reward" (Byrnes & Hayes, 2013), and personality traits and gender were found to influence liking and

Table 2
Examples of business engaging in food personalisation.

Name	Approach resulting in personalised:
www.mydietmealplan.com	Nutritional advice and meal plan
www.eatthismuch.com	Nutritional advice and grocery lists
my diet coach app	Nutritional advice and diet plan
MS-diet web app	Nutritional advice and diet plan including preferences and sustainability
Vireum communication platform app	Health related self-care recommendations and patient interaction
Foodoit platform	Dietary advice based on nutritional composition of foods and food recipes
Various retailers	Product offers based on previous purchases
Various online shops	Food gifts, cakes, delicatessen baskets, etc.

choice of food pungency (Spinelli et al., 2018). Individual differences in food neophobia (reluctance to try novel foods) and food neophilia (willingness to try novel foods) were shown to be mediated by psychological and personality factors (Raudenbush & Capiola, 2012) and are linked to sensory sensitivity, body weight and physical responses, such as the cephalic phase salivary response. Differences in cognitive style (analytic vs. wholistic consumers or fast vs. slow thinkers) were suggested to influence how people perceive and discriminate food (Varela et al., 2017).

Food-elicited emotions have been proposed as important determinants of food choice, depending on individual differences such as disgust sensitivity which can determine the openness to try new sources of protein, such as insects in food items, where men are more open than women (Haidt, McCauley, & Rozin, 1994). Emotional arousal could for example influence dysregulated eating, as restrained eaters are more likely to increase the amount eaten in response to emotional stress (Gibson, 2006).

A food choice that satisfies a person in one situation can be very different to another; one does not order the same foods and drinks in a business lunch, a first date or a meeting with old friends, being the same person with the same preferences, background and perceptual abilities. Köster (2009) proposes that perhaps "the consumer should be viewed as a variety of personalities that react differently in different situations".

5.3. Consumer marketing

Successful food product development requires understanding of personal choices (Dijksterhuis, 2016). Several approaches to consumer-driven product development utilise personal requirements to fulfil the needs of segments or target groups (Altintzoglou et al., 2010). Consumer orientation and empathy needed to understand personal requirements is found in various levels among people in key marketing positions (Bagozzi et al., 2011; Verbeke, Bagozzi, & van den Berg, 2014). The level to which food product personalisation is personal or group defined has not received enough attention, despite its known relevance (van Trijp & Ronteltap, 2007; Wind & Rangaswamy, 2001). Personalisation is feasible in some product categories, while in other, a segment approach could be more efficient. Defining consumer appreciation in the level of personalisation could be a useful starting point towards a reduction of mass-produced foods that fail to satisfy consumers.

European consumers, especially with health issues, report openness to food personalisation that matches their genetics (Stewart-Knox et al., 2009). Products resulting in a personalised diet would assist consumers if they carry clearly communicated product advantages in balance with information regarding pricing and peer support to allow for informed consumer choices (Ronteltap, van Trijp, & Renes, 2009; Ronteltap, van Trijp, Renes, & Frewer, 2007). Information on benefits towards personalised health needs should focus on the hedonic benefits of consuming this food, to motivate consumers towards the consumption of such products (Rusu et al., 2020). Marketing communication of such

products should be carefully and elegantly designed to avoid confronting consumers on a personal or on a social level. Research on consumer acceptance of marketing communication of special benefits in personalised foods would be a valuable field for future research.

Personalised food product development would challenge production lines and is mostly performed as personalised marketing to successfully reach consumers (Goldsmith, 1999), while allowing the pleasure of having a choice (Altintzoglou et al., 2015). Goldsmith (1999) considers internet shopping as the optimal environment for marketing on individual level. Retailing loyalty schemes also aim at understanding purchase behaviour and adapt special offers that fulfil consumers' habits for a lower price (Evans, 1999). Personalised marketing communication can shift consumer preferences toward specific goals (Haq, Whitelegg, Cinderby, & Owen, 2008), but its implementation may introduce challenges in terms of privacy and changing food culture (Cairns, 2013). Some common values, such as tasty, safe, sustainable and nutritious food are universal elements of all cultures. We know about consumer concerns in those relevant characteristics of food products and how they interact (Jacobs, Sioen, Marques, & Verbeke, 2018), but little is done on how these concerns reflect on actual behaviour.

Food product personalisation could also be achieved by combining food ingredients towards personal requirements and preferences, as seen in various current approaches (Table 2), while allowing consumers the joy of adding a personal touch that could increase their satisfaction with the food, and increase the benefits social interaction (Heide & Olsen, 2011; Xie, Bagozzi, & Troye, 2007). Studies describe consumer evaluation of information and products that they prepare themselves (Kole, Altintzoglou, Schelvis-Smit, & Luten, 2009), but the level of personalisation consumers can bring to food that they enjoy repeatedly is a level of insight that varies per person and situation. These instant preferences that fine-tune the coarse consumer preferences could be a challenging and valuable field to expand in future research.

6. Limitations

As food is the focus, it is not in scope of this paper to discuss technological approaches for measurement of physiological variables that allow for personalisation (e.g. biometrics, sensors to measure physiological constants, sensors which measure the relationship between food structure and eating behaviour), or software solutions (e.g. personalisation apps). Furthermore, the impact of gender or health status on personalisation of foods have not been discussed either. The area of food personalisation is at present very wide and can certainly deserve more than one paper reviewing the different approaches.

7. Conclusions

Personalisation of food can be addressed throughout the value chain of food from food raw materials until it is consumed and digested. It is not only about nutritional content but also about how food raw materials can be chosen, combined, processed and presented to fit personal requirements. In this paper, we have presented an overview of some aspects that can be instrumental in personalisation of foods. The overview is not comprehensive; for instance, the impact of social, cultural and specific medical conditions, such as allergies and intolerances, on personalisation of foods have not been discussed and warrant further attention. In addition, the challenge of providing information to consumers that differ in use of information channels and in type of information needed has not been addressed in this paper. Further research is needed to investigate the possibilities of combining food technology with consumers' specific characteristics to provide personalised foods.

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CRediT authorship contribution statement

Øydis Ueland: Conceptualization, Writing - original draft, Writing - review & editing. **Themis Altintzoglou:** Conceptualization, Writing - original draft, Writing - review & editing. **Bente Kirkhus:** Conceptualization, Writing - original draft, Writing - review & editing. **Diana Lindberg:** Conceptualization, Writing - original draft, Writing - review & editing. **Guro Helgesdotter Rognså:** Conceptualization, Writing - original draft, Writing - review & editing. **Jan Thomas Rosnes:** Conceptualization, Writing - original draft, Writing - review & editing. **Ida Rud:** Conceptualization, Writing - original draft, Writing - review & editing. **Paula Varela:** Conceptualization, Writing - original draft, Writing - review & editing.

Declaration of competing interest

None.

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