Chapter 5.1

Personalized Nutrition: Paving the way to better population health

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One billion people go to bed hungry every night, while half a billion of the world’s citizens are obese. In the developed world, a sedentary and affluent lifestyle in a society with immediate access to affordable food is the main driver of obesity. In developing economies, urbanization is the lead cause of obesity. Traditionally, public health nutrition education programs have followed a “one-size-fits-all” approach. In today’s digital age, this will change both in developing and developed countries as emerging information technologies come to dominate many traditional areas of communication. Nutrition education is no exception, and there is no reason not to believe that...
public health nutrition will be transformed to meet the unique needs of each individual citizen.

From 2011 to 2015, Food 4me, a European Union Seventh Framework project, explored the opportunities and challenges of personalized nutrition in addressing this increasingly concerning problem. Coordinated by University College Dublin and 26 partners across the EU, this project considered what might both help and hinder the development of personalized nutrition for all. The findings of Food 4me were published by the European Food Information Council in March 2015. They explore the concept of personalized nutrition from a scientific, technological, consumer, behavioral and business perspective.

**Origins of the concept of personalized nutrition**

Roger J Williams (1893–1988) was an American biochemist who named the B-vitamin folic acid and discovered another B-vitamin, pantothenic acid. In 1950, in an article entitled “Concept of genetotrophic disease,” Williams wrote thus: “A genetotrophic disease is one which occurs if a diet fails to provide sufficient supply of one or more nutrients required at high levels because of the characteristic genetic pattern of the individual concerned. This concept, based upon results in genetics and biochemistry, is new in medical thought and is believed to be the basis for many diseases, the causation of which is now obscure. Individual patients are far from standardized specimens, and medical problems should consistently be considered in terms of the genetically diverse patients, rather than in terms of an absolute normal.”

Thus the concept of genetically-based personalized health was first envisaged over six decades ago. It was to remain dormant for over half a century, however. The sequencing of the human genome changed those dynamics and led to a widespread belief that personalized medicine, in which therapeutic strategies would be targeted at patients on a genetic basis, was imminent. Soon, the term “personalized nutrition” began to emerge, accompanied by a belief that the nutritional management of diet-related chronic disease could be considerably improved on the basis of an individual’s genomic data. In 2003 – about the time of the release of the human genome – the Institute for the Future at Palo Alto issued a report on personalized nutrition which concluded as follows: “Analysis of the data shows that about one third of American adults are likely to make at least some decisions based on a knowledge of personalized nutrition by 2010. This will create an opportunity for a substantial transformation of the food and nutrition industry in the United States and elsewhere – especially for producers and packagers of foods, retailers, pharmacies, managers of magazines and health reports and health insurance.” Clearly, this prediction failed to materialize.

Against the background of such expectations of the potential of personalized nutrition, the European Commission’s Directorate-General for Research issued a call in 2009 for proposals to explore this area. The Food4Me consortium was developed in response, and submitted its proposal in 2010. The submission was successful, and the consortium began its program in April 2011, to run until March 2015. The project aimed to explore all elements of personalized nutrition, using a multidisciplinary approach. It delivered the most comprehensive analysis ever of personalized nutrition, taking full account of both the opportunities and the challenges of this exciting new concept.

**Definition of personalized nutrition**

The essence of personalized nutrition is not to change existing nutritional guidelines, nor to personalize food products, nor indeed to turn food into medicine, but rather to “assist individuals in achieving a lasting dietary behavior change that is beneficial for health.” Personalized nutrition can therefore be beneficial to everyone, whether they have already been diagnosed as at risk or they are perfectly healthy. It is an approach that helps everyone to reach the health condition to which they individually aspire.

Personalized nutrition makes healthy dietary suggestions more relevant to the daily life of the individual. Suggested changes to dietary patterns are therefore more effective and lasting. Food4me identified the need for combining the following approaches in order to achieve this.

1. A detailed knowledge of an individual’s food choices and resultant nutrient intake has to be established, using internet-based tools.

2. Based on that analysis, the individual needs to receive coaching on how to improve his or her nutrient profile by making better prevailing personal food choices.

3. The use of dried blood spot technology (through special
Personalized nutrition can benefit everyone, whether they have already been diagnosed as at risk or are perfectly healthy. Source: Mike Bloem

paper cards delivered in the post to each volunteer) allowed researchers to probe blood profiles so as to enhance the dietary analysis data in terms of understanding each volunteer’s unique nutritional profile.

4 Cheek swab samples were returned to the researchers to ascertain the genetic profile of each individual.

A six-month intervention study with over 1500 volunteers, carried out as part of Food4Me, showed this principle to be both feasible and effective. The mere fact that an individual receives dietary recommendations on a personal basis is enough to positively affect his or her dietary behavior. The effectiveness is higher, however, if the advice can be further personalized by providing detailed coaching on how each individual can modify his or her existing food choices so as to improve his/her own nutritional profile. Adding further information (such as blood-based biomarkers or genetic profiling) might result in even greater effectiveness, but this will require further research. The study also showed that it is feasible to deliver personalized dietary advice via an entirely internet-based interface, and that this approach provides a generally representative sample.
The scientific basis for personalized nutrition: Advice and lessons learned from a proof of principle study

Primary research questions:

Does **personalization of dietary advice** assist and / or motivate participants to eat a healthier diet in comparison with non-personalized, conventional healthy eating guidelines?

Is **personalization based on individualized phenotypic or genotypic information** more effective in motivating participants to make healthy changes, than personalization based on diet alone?

Secondary research questions:

Does **more frequent feedback help participants to improve** their compliance and motivate them to follow a healthier diet and lifestyle in comparison with those receiving less frequent feedback?
Recruitment flow chart

Interested individuals registered their details on the Food4Me website: [http://www.food4me.org/](http://www.food4me.org/)

Age, sex, internet access, pregnancy, food intolerances and allergies

First screening questionnaire

Demographic, health, anthropometric and dietary information

Food Frequency Questionnaire (FFQ) to estimate habitual dietary intakes

Excluded those who were pregnant, lactating, following a prescribed diet or having a food allergy or intolerance or not having access to the internet

Screening FFQ

Participants completed the online FFQ, took anthropometric measurements, started wearing PA monitors and sent buccal swabs and dry blood spot cards to the research team

Enrolment into study

Baseline FFQ DNA and blood sample

Participants in the high intensity group also completed the FFQ, anthropometric and PA at Month 1 and Month 2

Month 3 FFQ and provide blood sample

Month 6 FFQ and provide blood sample

Participants were provided with a personalized report (based on diet, phenotype and genotype) regardless of their intervention arm
Is personalization based on phenotype or genotype more effective than personalization based on diet alone?

Healthy Eating Index

Salt intake (g)

Saturated fat (% of total energy)
Will the effect of PN advice on body weight change differ between individuals with different starting body weights?

The graph above indicates the change in body weight between baseline and month 6 according to the body weight of individuals at baseline (lightest weight [Q1] to heaviest weight [Q5]). Individuals who were underweight gained over 1% of their body weight, compared with individuals who were overweight or obese, who lost up to 3.5% of their body weight.

At the outset, Food4Me recognized that personalized nutrition would operate on three levels, each of which could either stand-alone or else be combined:

- Personalized dietary analysis
- Personalized phenotype analysis
- Personalized genotype analysis.

The design of the proof-of-principle study presented some novel challenges to the consortium, particularly the recruitment of subjects into a study where all contact between researchers and subjects was via the internet or the postal services. A standard operating procedure of some 900 pages was constructed to ensure consistency in a detailed protocol across each of the seven participating centers (Dublin, Reading, Warsaw, Athens, Pamplona, Munich and Maastricht).

Two centers started ahead of all the rest and, based on their experience, modifications to the standard operating procedure were made, and an intense training program was initiated. The proof-of-principle study kicked off in June 2012 and ended in March 2014. All objectives, milestones and deliverables were achieved which, given the scale and novelty of the study, remains a credit to all involved.

Food4Me recognized that without a detailed understanding of consumer attitudes to personalized nutrition, any insight in this field would fall well short of ideal. Thus a very significant part of the work program was devoted to probing the opinions of EU consumers. An extensive focus group study was carried out in nine participating centers, leading to the development of a questionnaire that would then be administered to 1,000 subjects in each of these centers. In addition, about 700 of those who actually participated in the proof-of-principle study undertook this same questionnaire. The consortium also probed the legal and ethical aspects of delivering personalized nutrition, as well as scoping existing and emerging technologies that individuals can use to learn about their health and lifestyle.

The outcome is an extremely valuable database, which can now be mined to address the many complex questions that will be asked regarding consumer attitudes to personalized nutrition. Allied to an understanding of consumer attitudes to personalized nutrition is the need to understand the viability of any personalized nutrition enterprise, whether driven by social or by private entrepreneurship. Across a series of workshops with stakeholders drawn from a wide range of interested sectors, a number of scenarios were developed which will help shape our thinking about the viable alternatives for the creation of a sustainable personalized nutrition offering.

### Consumer responses to personalized nutrition

Consumer responses to the concept of personalized nutrition were found to be surprisingly positive. The perceived health benefits and the self-efficacy in managing personalized nutrition were seen to significantly outweigh any perceived risks.

Consumers share strikingly common views as to the criteria for an acceptable personalized nutrition service. These are:

- Person-to-person contact (either by email, phone or Skype, or else face to face)
- Direct access to an expert advisor who is perceived to have a professional background
- Regular follow-up on the advice given
- Advice covering not just nutrition but also physical activity and lifestyle recommendations.

Consumer attitudes vary much more widely when it comes to who should pay – the individual or public healthcare. They also disagree about what kind of arguments they find most persuasive – scientific explanations on the one hand, or experience-based evidence on the other. Some consumers may prefer group coaching over individual coaching, and some will favor a radical change of diet over a gradual adaptation. There is also greater reservation vis-à-vis genetic profiling than vis-à-vis blood analyses.

Consumers perceive risks especially related to privacy, personal data safety and potential misuse, either by authorities or companies, or as a result of hacking. It is possible that such risks are more keenly perceived when using the internet as an interface, as was the case in Food4Me.
Food4me also looked into the wide range of novel technologies that play an important role in enabling personalized nutrition. From the diagnostic phase (monitoring and assessing a person’s nutrition and health status) to generating dietary advice and making it practically applicable in daily life, technologies are essential for personalized nutrition. While individual genotyping is most often referred to in personalized nutrition, the growing number of diagnostic tools that help to assess the detailed physical and metabolic profile of an individual are probably more important and relevant. Food4Me explored the usefulness and reliability of some of these technologies. For example, dry blood spot sampling was used in the intervention study and was shown to be a very reliable and alternative sampling and measurement tool for a wide range of biomarkers from blood. Moreover, with proper video instructions, consumers were perfectly capable of taking their own blood samples, thus avoiding having to visit a doctor.

Self-measurement will be important in personalized nutrition, as most people want to be more independent and in control. Food4Me has shown that self-measurement of body parameters, physical activity and dietary intake is perfectly feasible when integrated into their lives – for example, by means of on-line food frequency questionnaires or wearable physical activity monitors. Novel technologies for wearable and on-line monitoring devices are emerging every day and will eventually allow us to measure a wide range of physical parameters, from glucose levels to vitamin status and from blood pressure to sleep quality.

Technical solutions are equally important to enable the coaching and follow-up of dietary behavior or to measure the progress of a person’s nutritional status against the objectives set. Using the internet and mobile communications, consumers could have a choice of direct interfaces in any situation to support appropriate food choices. These can come in a variety of forms – from apps such as on-line shopping assistants to appliances such as intelligent fridges and 3D food printers, or in the form of complete services such as home-delivered catering. This is how consumers will mostly experience the practical use of personalized nutrition. What they will not see is how these services rely on complex algorithms that convert a variety of information streams into a set of nutritional recommendations and, further, into food and meal plans that fit personal preferences. In this respect, Food4me successfully demonstrated the feasibility of such an integrated approach and its delivery through an on-line dietary advice system.

The role of technology in personalized nutrition

Self-measurement will be important in personalized nutrition, as most people want to be more independent and in control. Source: Mike Bloem

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Making personalized nutrition available to society at large

Much more effort will of course be needed before personalized nutrition can benefit society at large. While the volunteers in Food4Me demonstrated that the concept is useful for everyone, it will be a formidable challenge to introduce it to those who are most in need of a better diet, and who are often least interested in changing their dietary behavior.

Food4me explored what supportive business model concepts might possibly emerge in the future. Because dietary behavior and matters of nutrition and health are deeply rooted in societal issues, introducing personalized nutrition will inevitably involve significant societal changes. The timing is right for these changes, as our society urgently needs to take measures to tackle its growing health and nutrition problems.

Given the size and urgency of the problems and the fact that everyone should have the right to benefit from better health through personalized nutrition, a government-led initiative seems the most logical way of making personalized nutrition available to society at large. However, such a development is considered unlikely because governments are inherently reluctant to change such complex systems as public healthcare and also because of the sheer complexity of centrally organizing a personalized nutrition offering.

Personalized nutrition involves a wide range of actors, from diagnostic labs to producers of monitoring devices and app developers, and from advice algorithm developers to big data storage and analysis services. There will be an equally diverse constellation of users, most of them operating as intermediaries between the personalized nutrition service provider and the consumer/patient. These will range from dieticians, nutritionists and doctors, through hospitals, nursing homes, schools and day-care centers, to fitness centers, wellness institutions, retailers, caterers and restaurants, as well as health insurers and employers.

Personalized nutrition providers will thus become new and important integrating actors in society. Private initiatives are therefore the most likely way to drive the introduction of personalized nutrition services, probably with some form of societal support, preferably in the form of public/private partnerships.

Future business models are thus likely to involve networked structures with distributed profit centers that will work in close relationship with communities and other societal actors.
Legal and ethical considerations

In the light of the profound impact it will have on society, the introduction of personalized nutrition also raises important legal and ethical concerns. These too were examined in depth by the Food4Me project.

As personalized nutrition is making “nutrition-related” health the explicit responsibility of the individual, it will change the way our society views food and its role in health. This will affect the solidarity principle on which health insurance has until now been based. This will happen because personalized nutrition will lift this “veil of ignorance” when it comes to nutrition-related health issues.

The introduction of personalized nutrition brings to the fore concerns about personal freedom (especially if some people prefer not to be informed about individual health risks). It also raises questions about fairness in the system, particularly as concerns those deemed to be at higher risk.

There is also an issue over social inequality and injustice, since not everyone will be able either to understand or to react appropriately to the advice (or even to afford to follow it), while at the same time others might willfully and knowingly ignore this advice and refuse to change any behaviors.

These are complex issues. Significant changes to public healthcare and health insurance systems will therefore be required in order to maintain a balance between the interests of the individual and the common good.

On top of this, the present legal frameworks on food and health afford very little scope for providing this approach to personalized nutritional. Significant changes will be needed when it comes to regulating privacy (personal data access rights and data storage security). This holds true especially for mobile- and internet-based interfaces.

Similar steps being are taken right now towards personalized medicine, and these may also help us find a clearer distinction between nutrition-related health and uncontrollable health risks and the possible new roles that different actors will have as these definitions change.

Personalized nutrition in developed and less developed economies

Chapter 4.3 of this book highlights some of the challenges of technology transfer in the field of personalized nutrition. The Food4Me project focused on a collection of samples and data in affluent EU states. However, all of those technologies – personalized nutrition analysis, personalized anthropometric analysis and personalized genomics – are transferrable to less developed economies. In particular, dried blood spot technologies, as used in Food4Me, offer a rapid, inexpensive, low-technology and mass-distributive solution for blood collection which can be subsequently used for routine blood analysis or more advanced metabolomics analysis using the “hyphenated” (GC/LC/MC and NMR) technologies.

The developments in “Nutrition-workforce capacity building” as outlined in Chapter 4.3 provide the initial input into the building-blocks of personalized nutrition. Digitized personal data can be entered into such systems to help explore personalized nutrition using simple food consumption study methods. Most importantly, this technology can deliver photographic images of food servings, which have much greater communicative potential than linguistically based approaches. Ultimately, e-health in all its aspects will be like the smartphone: ubiquitous and adaptable.

Developing a more positive attitude toward diet and health

It seems possible that, at some point in the future, the move towards personalized nutrition in our society will fundamentally change people’s perception of food and its role in health.

With each individual accepting his or her own responsibility for health, and effective use of the technologies that allow us to monitor this and make it happen, our society will gain a growing sense of being in control, and will develop an altogether more positive attitude toward diet and health.

For the majority, it will be enough to have the reassurance that potential health risks are under control. By these means, health will be turned into a manageable asset. For a growing percentage of the population, however, personalized nutrition will represent an opportunity to achieve optimal health. The concept of “health” itself will therefore evolve from one centered on achieving basic health goals to one involving the attainment of a much higher level of knowledge, understanding and self-awareness. Personalized nutrition will support self-realization, both within the realm of health and beyond it.
Food4Me partners

1 University College Dublin
2 Ulster University
3 Maastricht University
4 Newcastle University
5 University of Oslo
6 University of Navarra
7 Lund University
8 University of Reading
9 Crème GlobalSoftware Ltd.
10 European Food Information Council
11 National Food and Nutrition Institute, Warsaw
12 TNO Quality of Life
13 Harokopio University, Athens
14 Wageningen University
15 LEI-Wageningen University Research
16 Philips Netherlands
17 Technical University Munich
18 NuGO-A Association
18 Keller and Heckman
20 Philips UK
21 Vitas
22 HLK
23 Porto University
24 Bio-Sense
25 DSM Nutritional Products Ltd
26 University of Bradford

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Food4Me has demonstrated that the internet-based delivery of personalized dietary analysis and advice is not only feasible but also highly attractive to consumers. It has additionally shown that, in the light of the increasing age profile of the internet- and social-media-savvy consumer, the emergence of personalized nutrition is a given. Popular smartphone apps will come and go, but they will – at least for the foreseeable future – lack the complexity of the IT technology seen in Food4Me.

Beyond the simple 20-minute session a consumer might spend on the internet to attain a personalized dietary analysis and nutritional coaching, the next phase will be to integrate that service with smart kitchens, with retailers, and with works canteens. In the white goods industry, there is intense interest in bringing technologies directly into the home kitchen so as to enable consumers to optimize home cooking in order to attain improved nutrient profiling.

This is one step away from linking the home kitchen to the electronic dimension of supermarket purchasing and another step away from the selection of foods at works canteens. The integration of all this data will happen, and the consumer of the future will be able to plan and manage a week’s menu so as to optimize gastronomic aspects, price and nutritional wellbeing. As Edwin Land, the MIT professor who pioneered Polaroid photography, said: “The present is the past, biting into the future.”

**Further reading**

