Active Ageing and Healthy Living
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Nutrition and Ageing

Andrea MINUTI [a], Vania PATRONE [a], Gianluca GIUBERTI [a], Giorgia SPIGNO [a], Amedeo PIETRI [a], Paola BATTILANI [a], Paolo AJMONE MARSAN [a1]
[a] *Faculty of Agriculture, Food and Environmental Science, Università Cattolica del Sacro Cuore.*

Abstract. The world elderly population is rapidly increasing. This demographic change represents a new challenge for the society and demands for a multi-sectorial intervention to promote a long, healthy, and active life span. Between the factors that contribute in fostering a long healthy life, the nutritional regime plays a central role and is recognized as a major factor in the onset of chronic diseases. A better understanding of the interaction between nutrition and ageing is essential to unravel the mechanisms responsible for these positive/negative effects and to identify diet components promoting the quality of life in the old age and to contribute to the prevention of late-life disabilities. At Università Cattolica del Sacro Cuore, the research activity in food science is focusing on four main objectives: food quality, food safety, functional foods and diet balancing. These objectives are the target of multidisciplinary ongoing and future research activities for a better understanding of the link between diet and ageing. Briefly, the different activities are addressed to the study of the following subjects: the most relevant factors affecting food choices and habits of old aged persons; the effects of long term low dose supplementation of conjugated linoleic acid in mouse; the use of low glycemic index and high resistant starch foods to prevent diabetes and obesity; the adjuvant effect of food bacteria for vaccination; the role of food ingredients in disease; the immunosuppression effect of mycotoxins, and its relevance in ageing people; the production of sustainable and natural antioxidant ingredients to encourage a healthy diet. Our research projects emphasize an holistic and integrated approach that, by bringing together complementary research groups, can combine the collective expertise and thus provide a comprehensive assessment of the role of nutrition in healthy ageing people.

Keywords. Nutrition, ageing, diet, elderly

Introduction

The proportion of the global elderly population (> 65 years) is increasing rapidly and is set to rise further; it is estimated that, by 2025, there will be a total of about 1.2 billion people aged over of 60 [1]. Like the rest of the world, the European Union is characterized by an ageing society. This demographic change implicates new challenges involving different areas of intervention (e.g. social, psychological, economic, medical, physiological, nutritional). A long and healthy life span involves many factors, such as diet, genes, exercise, productive pursuits and social activity. The

[1] Corresponding author: Institute of Zootechnics and Nutrigenomics and Proteomics Research Center - PRONUTRIGEN, Faculty of Agriculture, Food and Environmental Science, Università Cattolica del Sacro Cuore, via Emilia Parmense, 84, 29122, Piacenza, Italy. E-mail: paolo.ajmone@unicatt.it

knowledge of these factors and their interaction can contribute a long and high-quality life. Among the different factors involved, it is well established that diet plays a central role for health, having long-term consequences throughout life. It is one of the lifestyle components that contribute to the development and progression of chronic diseases, including cardiovascular diseases, diabetes, and cancer. A greater understanding of the interactions between nutrition and ageing is essential in order to develop new approaches to improve the quality of life of elderly people and prevent later-in-life diseases.

Human biology is quite complex. Networks of biochemical reactions interact to maintain cell, tissue, organ, and organism homeostasis in a changing environment. After the age of fifty, many physiological changes occur in the body. The metabolic rate slows down, and it can decline by as much as 30% over a lifetime. The body composition changes with a reduction in lean body mass and an increase in fat mass, which facilitates the onset of systemic inflammation, insulin resistance, and metabolic syndrome. The digestive system efficiency decreases, due to lower gastric and enzymatic secretion, and reduced absorption ability. A balanced diet maintains the functionality of the gut mucosal barrier, a proper intestinal microflora that contributes to homeostasis and decreases the risk of alterations associated with chronic disease conditions.

Older people might not be getting a balanced diet for a number of reasons; these may be psychological, physiological, or simply economic. Therefore, it seems relevant to consider a whole range of socio-economic and cultural factors that influence the food choices of old persons, and affect active ageing in order to ensure a healthy diet.

1. Diet, Active Ageing, and Healthy Living

Willet [2] emphasized that genetic and environmental factors, including diet and lifestyle, both contribute to cardiovascular diseases, cancer, and other major causes of mortality. Hence, environmental factors may certainly have the strongest influence on life expectancy and hence lifespan [2, 3]. Nutrition is coming to the foreground as a major modifiable determinant of chronic diseases, with scientific evidence increasingly supporting the view that alterations in diet have strong effects, both positive and negative, on health throughout life. Most importantly, dietary adjustments may not only influence current health, but may also determine whether or not an individual will develop chronic diseases much later in life [4]. Obesity in humans, influenced by poor dietary choices and inactivity, is significantly associated with an increased risk of chronic diseases such as diabetes, high blood pressure, high cholesterol, cardiovascular diseases, asthma, arthritis, some cancers, and overall poor health status, which can significantly decrease an individual's life expectancy [5]. For instance, it has been estimated that, in 2000, there were approximately 150 million individuals with type-2 diabetes, and this number is likely to double by 2025 [6].

Based on the above statements, the role of nutrition appears to be fundamental for a high quality of life and healthy ageing.

2. Our research activity

At Università Cattolica del Sacro Cuore, research in Food Science is focusing on four main objectives, briefly described as follows.

- *Food quality*. Health conditions and well-being of individuals are strongly influenced by food choices. Excess intake of sugars and saturated fats represents a major dietary concern as well as under-consumption of fruits and vegetables.
- *Food safety*. This is an important public health issue and a major concern for elderly people. Normal ageing is associated with a general decrease in immune function, which is further impaired by specific disabling conditions such as chronic diseases, need for medication, and malnutrition, which are more frequently experienced by older individuals. As a consequence, older people may face increased susceptibility to foodborne illness as compared to other population subsets [7]. In addition, they are more likely to experience serious or long-term infection complications that may result in prolonged hospitalization and eventually death.
- *Functional foods*. People can optimize the health-promoting capabilities of their diet by supplementing and consuming foods that have been formulated or fortified to include health-promoting factors. Functional foods are components of the usual diet that may have special disease-prevention attributes. According to the Food and Nutrition Board of the Institute of Medicine, a functional food is "any food or food ingredient that may provide a health benefit beyond basic nutrition" [8]. Unlike dietary supplements that can claim only general health benefits, functional foods may claim specific health benefits since they are considered part of the diet [8].
- *Diet balancing*. Understanding the effects of dietary macronutrients on ageing remains a fundamental challenge, with profound implications for human health [9]. Often, the focus of nutrition research is on the effects of individual macronutrients (fat, sugar, and protein). However, studies on a wide range of species provide growing evidence that macro-nutrients' interaction (i.e., their balance), in addition to their individual dosage, is important for health and ageing [9–11]. Defining what represents a balanced diet, and the consequences of not attaining such balance, is of high priority in nutrition research.

These objectives are the target of multidisciplinary research activities currently underway or planned in the near future for a better understanding of the link between diet and ageing.

2.1. Factors affecting a healthy diet for the elderly.

The elderly are a segment of the population that is rapidly growing; policy makers are seeking interventions to guarantee high health status and quality of life and to individuate care-giving practices to meet the needs of the elderly. The quality of diet (nutritional content, food safety) is a key element of older people's well-being, and addressing the issue of food choices for the elderly may provide valuable information for policy makers and care givers. For elderly individuals, inadequate nutrition can increase the incidence and severity of disease, thus hastening the loss of independence.

The choice of a healthy and a varied diet is challenging for people aged 60 or above, because the ability to choose a diet which meets their nutritional needs may be adversely affected by the pathological, physiological, economic, and societal factors that accompany ageing [12]. Thus, to better understand and solve the nutritional problems of the elderly, it is important to identify these factors and how they affect food choices [13].

The objective of the study is to analyse the most relevant factors affecting diet in the elderly (health-related, socioeconomic, cultural, bio-legal and ethical, life-style), and individuate the causal relations among collected variables and food habits.

2.2. Diet and Animal Models of Ageing: The effects of long-term low-dose supplementation of conjugated linoleic acid in mice.

Ageing leads to a reduction in lean body mass and an increase in fat mass facilitating the onset of systemic inflammation, insulin resistance, and metabolic syndrome. Inflammatory processes, no longer controlled by the immune system, cause accelerated immunosenescence. The condition of progressive loss of skeletal muscle mass and strength is termed "sarcopenia". On average, ageing individuals lose muscle mass at a rate of 1–2% per year after the age of 50, resulting in a significant decrease of muscle strength [14].

Conjugated Linoleic Acid (CLA) refers to a mixture of positionally and geometrically conjugated dienoic isomers of linoleic acid [15]. Over the last several years, interest in CLA has increased due to its many bioactive properties related to health. The benefits seem to be very clear, especially in some experimental animal models. The health effects attributable to CLA include anti-carcinogenic and anti-tumorigenic effects [16]; reduction in the risk of atherosclerosis, hypertension, and diabetes; improvement in food efficiency; promotion of energy metabolism and body weight [17, 18]; positive effect on immune function [19]; and musculoskeletal health [20].

The general objective of the study is to investigate the effect of a long-term low-dose supplementation of two CLA isomers (c9t11 CLA and t10c12 CLA) and their mix in a mouse model. In particular, will be investigated the effect of CLA on metabolism, inflammatory response, and the immunity status and gene expression modification in different tissues (liver, abdominal fat, cardiac muscle, skeletal muscle, brain) as well as in tissues composition and in mitochondrial activities.

2.3. Use of low glycemic index and high resistant starch foods to prevent diabetes and obesity in elderly people.

One of the consequences of ageing is the increase of body weight and body fat percentage. Both of these conditions facilitate the initiation of chronic inflammation, insulin resistance, and metabolic syndrome. For instance, epidemiological and experimental studies reveal that the prevalence of type 2 diabetes may increase with age, although the patterns of incidence vary noticeably [21]. A wide range of lifestyle-related factors has been implicated, including early-life events and physical inactivity, several dietary attributes (i.e., quantity and quality of dietary fat and carbohydrates), and the subsequent development of overweight and obesity. Metabolic studies have shown that food sources of carbohydrates vary greatly in the rate of absorption and effects of blood glucose and insulin concentration, with several implications in the

physiological response and overall health status [22]. One way to quantify this variation in response to dietary carbohydrates is the glycemic index (GI), pioneered by Jenkins et al.[23]. Consumption of low GI foods has been related to reductions in the risk of coronary heart disease and type 2 diabetes [22, 24]. A similar benefit has also been shown with high-resistant starch (RS) foods [25]. This fraction shares several common properties with soluble dietary fibre, and a significant number of studies have indicated that RS-rich foods release glucose slowly, thus potentially resulting in a lowered insulin response, greater access to and use of stored fat, and potentially a muted generation of hunger signals [26–28]. Accordingly, it has been proposed that eating a diet rich in RS may potentially increase the mobilization and use of fat stores as a direct result of the reduction in insulin secretion [29]. In addition, the consumption of high-RS food can increase the production of volatile fatty acids (especially butyrate) and therefore may help to improve colonic health with possible implications in the treatment and/or prevention of disease such as colorectal cancer [30].

Since a positive correlation between GI and food intake is well established, the development of low-GI and high-RS foods can be a suitable tool in reducing the risk of ageing-related illness. Low-GI foods can be obtained by the use of specific ingredients (sources of RS) or by technical treatments or combining the two approaches. The innovative aspect of our proposal is the use of a new source of RS, combined with technical treatments, to favorably reduce the GI of foods.

2.4. Adjuvant effect of food bacteria for elderly vaccination

Among the dramatic physiological changes experienced by human individuals during ageing are the alterations in the structure and functions of the human gut microbiota. In elderly subjects, such shifts of the intestinal microbial populations might be linked to immunosenescence and inflammaging; i.e. the decline of immune response that occurs with age and the concomitant increase in inflammatory status [31]. Recent data suggest a correlation between diet, gut microbiota, and frailty status in the elderly [32], thus supporting the potential health benefits of a dietary intervention targeting the gut microbiota. In this context, it has been suggested that probiotics, through their effect on immune regulation, can influence a number of common conditions typical of advanced age, such as increased susceptibility to infection. Moreover, the effectiveness of vaccinations in preventing illness is lower among the elderly, and this represents a public health problem, causing a considerable societal cost. There is promising evidence that bacteria usually incorporated into fermented foods (yoghurt) or used as active ingredients in food supplements have an adjuvant effect in supporting the effect of vaccinations in the elderly. This effect includes the influenza vaccine, which is provided for free to the elderly by some European national health services. This effect seems related to specific bacterial strains and is not widespread among the so-called probiotic bacteria. The scope of the proposed investigation includes providing solid clinical support to the existing data as well as a pharmacoeconomics evaluation of the use of these bacteria within the national vaccination programmes. Additionally, the research activity will focus on developing reliable in vitro assays to explore the molecular mechanisms at the basis of this effect.

2.5. The role of food ingredients in disease; i.e. sodium chloride in processed meat and cheese

Ageing brings a dramatic increase in the prevalence of hypertension associated with a greater risk of stroke, heart attack, and other heart-related diseases [33]. Scientific evidence accumulated in the last decade indicates that a diet high in salt can cause raised blood pressure, and changes in diet are recommended to lower it [34]. Salt is traditionally used as a natural ingredient in the making of preserved food such as processed meat and cheese to add flavour and extend the shelf life. As a result, health-related food quality characteristics such as low levels of salt are increasingly demanded by consumers; on the other hand, consumer concerns about food quality can significantly reduce the demand for traditional food products. The specific challenge in traditional food production is the improvement of the safety and the nutritional value profile of European traditional foods such as processed meat (salami and sausages) and cheese in the frame of typical food (Protected Designations of Origin [PDO]) products. The scope of this investigation includes identifying support of the health status of the ageing European population while allowing them to consume the traditional (PDO) food products to which they are accustomed. The goal is to improve the health status of ageing people without changing their nutritional habits, and to support the European food industry, mainly formed by small and medium enterprises (SMEs), to "restyle" traditional food products.

2.6. Immunosoppression effect of mycotoxins and its relevance in ageing people .

Human food can be contaminated with mycotoxins at various stages in the food chain [35], even if the mycotoxins that are likely to be encountered by human populations differ between countries [36]. The EU regulation sets limits for the most toxic compounds, defining stricter values for baby food. When ingested, mycotoxins may cause mycotoxicoses that can result in acute or chronic disease episodes [37]. The toxic effects of mycotoxin ingestion depend on a number of factors, including intake level, duration of exposure, toxin species, mechanism of action, metabolism, as well as defence mechanisms [38]. In Europe, concern is mainly due to chronic effects. In fact, it is well known that some mycotoxins cumulate in time and have relevant persistence in organs like liver and kidney.

Mycotoxins are confirmed/potential carcinogens; they have several undesirable effects, but one of the less-studied toxic effects is immunosuppression [39]. The multi-mycotoxin exposure and their synergistic effect is a further matter of concern.

It is expected that older people are more at risk of adverse health effects caused by mycotoxins, both as a result of the high accumulation in organs and their higher susceptibility compared to younger adult people. In this context, it is important to study ageing people's exposure and determine how mycotoxins can influence their well-being in order to plan counter actions, if necessary.

The general aim of the study is to understand the role of mycotoxins on ageing people's health in order to (i) suggest a more suitable diet, leading to lower exposure to mycotoxins, and ii) propose stricter limits on mycotoxin content in food products, similarly to those in force for baby food. In addition, the definition of appropriate biomarkers should help in better evaluation of mycotoxin exposure.

2.7. Production of sustainable and natural antioxidant ingredients for a healthy diet for the elderly.

Antioxidants, particularly the polyphenolic forms, may help lower the incidence of disease, such as certain cancers, cardiovascular and neurodegenerative diseases, and DNA damage, and may even have anti-ageing properties [40]. A diet rich in polyphenolic forms of antioxidants can promote healthy ageing [41]. If the definition of both the required pharmacological doses and bioavailability of phenolic compounds is required, the production of functional foods rich in polyphenols is also required.

Wastes and residues from agriculture and food processing are often still rich in polyphenolic compounds. Antioxidant polyphenols that have been recovered from residual sources represent potential low-cost functional ingredients provided that a low-cost recovery process is applied. Extensive research has been done in the last decades on the recovery of polyphenols from residual sources, thus revealing the feasibility of such processes. The recovery process needs to be completed through purification and encapsulation steps which need to be tailor made for specific applications (such as bakery products, rather than beverages or dairy products). However, the recovered compounds are to be further processed in order to deliver stable and efficient formulations to be incorporated into functional foods. The final formulations have to be characterized by high antioxidant activity, stability in the target food product, and release in the human body (following the digestion process or also as a probiotic/prebiotic effect).

The project aims to develop different innovative functional foods through the addition of antioxidant ingredients produced from agri-food residuals. The conducted research will contribute to advances in the state-of-the-art research related to the encapsulation of polyphenolic compounds for their protection during food processing and, at the same time, for a suitable stability and release into the human body after ingestion.

3. The practical value of this research activity for active ageing and healthy living

The various ongoing and future research projects at Università Cattolica del Sacro Cuore focusing on nutrition and ageing are expected to yield multiple and significant practical benefits.

Nutrition research will produce new knowledge about how nutrients affect human physiology, the connections between food and human health, and their significance in the development of late-in-life diseases. Risk-assessment research will help to characterize the specific nature and magnitude of risks for elderly people's health associated with foodborne hazards such as mycotoxins. The results of these works of research will provide information and resources to guide dieticians and healthcare professionals in decision making and professional practice regarding food and input into local and national-level nutrition policy decisions that may reduce disease risk and/or promote good health in elderly people.

Research in food science will contribute to the development of new methods and combinations of ingredients in food preparation and preservation to be applied in traditional food production systems aimed at preserving the quality and typicality of the products while at the same time meeting the nutritional needs and dietary recommendations for healthy elderly population, such as lower salt intake. The transfer

of such technologies to traditional food producers will contribute to the support of this industrial sector and increase their competitiveness through innovation without affecting senior European consumers' attitudes towards traditional food. At the same time, the applied research will design new functional food and nutrition solutions to provide specific health benefit for older people over and above their basic nutritional value. This includes the development of foods with a low glycemic index, which promotes satiety and improves blood glucose control for weight management and better metabolic health, as well as food enriched with antioxidants, which may support physical performance and cognitive function in seniors. The possibility of using agri-food residuals for this purpose will encourage environmentally responsible practices that conserve natural resources, reduce the quantity of waste generated, and support the ecological sustainability of the food system.

In the context of delaying adverse health conditions, the output of the research will offer new possibilities and nutrition strategies to improve established preventative care measures in older people, above all vaccinations. Effective primary prevention in older individuals results in significant reductions in hospital admissions and net healthcare costs, with positive economic and social implications for society as a whole.

Making effective recommendations for healthier nutrition in elderly people entails understanding the influence of economic factors, physical conditions, personal perceptions, and household characteristics on the dietary choices of older adults. The comprehensive collection and analysis of data concerning these aspects will shed new light on the issue of food choices among the elderly, with main reference to the quality of the diet and food safety, and will allow the use of new knowledge to assess specific interventions targeting the elderly and mainly among caregivers such as family doctors and physicians.

4. Conclusions

Scientific research into the complex interactions between nutrition and health as part of the ageing process is of great significance in light of the current worldwide growth of the elderly population. Such research offers a challenging opportunity to develop evidence-based strategies to enhance healthy ageing through diet, with an emphasis on preventing chronic disease, minimizing physical and mental impairment, and improving the overall quality of life in late adulthood.

To address these issues nutrition science must take into account the development of innovative technologies and processes and their impact on food systems on one side and the social, economic, and cultural dimensions of older individuals' nutrition behaviour and habits on the other.

Our research projects emphasize a holistic and integrated approach that, by bringing together complementary research groups, can combine the collective expertise and thus provide a comprehensive assessment of the role of nutrition in healthy ageing.

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