1 Introduction

Background and motivation for the work underlying this thesis

During the past decade there has been increasing evidence that nutrition plays an important role in the development of lifestyle diseases such as cardiovascular diseases (CVD) and type 2 diabetes mellitus (T2DM), which are growing problem in the Western world. It has generally been believed that a reduction or substitution of energy from saturated fat is an important dietary approach in preventing and reducing CVD, which has led to national health policies recommending a reduction in intake of foods that contain a high amount of saturated fat. Dairy products are a food group containing a high amount of saturated fat, and dairy product consumption has therefore been linked to an increase in CVD risk. Furthermore, the majority of the well-known cholesterol-raising saturated fatty acids (SFA) (12:0-16:0) in the human diet are delivered from dairy products.

Recent studies have, however, indicated that the issue may be more complex. A number of recent meta-analyses, including mainly prospective cohort studies, fail to find and association between dairy product consumption and CVD risk and mortality (1,2). One analysis found no association between milk consumption and total mortality, and indicated that there might even be a modest protective effect on overall CVD risk (2). Another analysis found a reduced risk of all-cause mortality, ischaemic heart diseases (IHD), and stroke among subjects consuming high versus low amounts of milk and dairy products (1). In addition, recent results from observational studies failed to find an associations between plasma cholesterol and CVD risk (3). Furthermore, a recent meta-analysis including mainly prospective cohort studies found an overall reduced risk of T2DM incidence among subjects consuming high versus low amounts of dairy products (4). Hence, these results might obviously reflect some unknown confounder effects, but could also indicate that dairy products contain some components that could counterbalance the negative effects of the highly saturated fats found in dairy products.

In addition, this has given rise to the hypothesis that milk contains a beneficial "milk factor", which somehow modulates the cholesterol raising effects of milk fat. Milk is a very rich source of potentially bioactive lipids. Phytanic acid (PA) has been suggested to prevent certain metabolic dysfunctions related to the metabolic syndrome (MS) and T2DM (5). These effects have been partially explained by PA agonist activity towards the nuclear receptors, peroxisome proliferator-activated receptors (PPAR) and retinoid-X-receptors (RXR) (6-9); these have important functions in the glucose and lipid metabolism (10-14). However, the physiological effect has not yet been tested *in vivo*, when PA is consumed in concentrations similar to the concentration found in foodstuff. In addition, observational studies have shown that the plasma PA level in normal humans varies with dietary habit (15,16), whereas the strongest determinant of plasma PA concentration appears to be dairy fat intake (15). However, this correlation has not yet been examined in human dietary inter-

vention studies, which is important with regard to the understanding of PA's potential as a nutritional regulator of nuclear receptors.

There has been considerable interest in developing sustainable nutritional strategies to enhance the concentrations of specific fatty acids (FA) and bioactive lipids in milk with the potential to improve long-term health. In addition, strategies for enhancing the nutritional value of milk fat include reducing the proportion of SFA and increasing *cis*-monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) content and/or enhancing the concentration of bioactive lipids (17). Altering the FA composition of milk to achieve a FA profile consistent with public health recommendations has been extensively studied (17). However, only very few human dietary intervention studies have examined the effects of modifying dairy products on CVD and T2DM risk markers (18-25). PA content can be modified through cow feeding regimes, and studies have shown that increasing the amount of green feed to cows increases the content of PA in milk fat (26,27). However, the effect of dairy fat delivered from mountain-pasture grazing cows, which would result in a substantially higher concentration of PA as well as other bioactive FA, have not yet been investigated.

During the past few years climate change has been recognized as the major environmental problem facing the world. Food production cause multiple strains on the environment and these negative impacts are estimated to increase due to population growth. The Environmental impact of products (EIPRO) study conducted in 2006, estimated that foods are responsible for 30 percent of all anthropogenic greenhouse gas emissions (GHGE) released within the EU (28); thus, one of the great challenges is to reduce the GHGE resulting from our production and consumption of various foods. Although, a broad range of environmental impact categories influence the climate impact of food, including water and land use, waste disposal, erosion, biodiversity loss, eutrophication and GHGE, the focus of the present PhD thesis is on the GHGE related to the food.

Several studies have investigated the connection between food and climate impact using life cycle assessments (LCA), estimating GHGE from "cradle to grave" (29,30). Animal based products are generally associated with relatively large GHGE on a per kg basis compared to vegetable products (30,31), and makes the greatest contribution to GHGE in the diet (32-34). Therefore, a change toward a less animal-dependent diet is also one of the solutions often suggested to reduce GHGE. However, products of animal origin also have an important place in a healthy diet because of their high nutritional value.

LCA is solely a measure of the climate impact in relation to a specified weight of the food item and does not include the nutritional quality of the food. Consumption of foods from all food groups, compliance with energy requirements and macronutrient profiles, is linked to an adequate intake of nutrients and a decreased risk of non-communicable diseases (35). Generally, one food group cannot be replaced by another (36). Thus, it is inadequate to compare e.g. apple and beef only by the GHGE per kg product. Hence, when discussing the need to reduce the GHGE caused by the food

sector, it is crucial to consider the nutritional value of alternative food choices and not solely focus on impact per kg product.

Study aims and hypotheses

The overall aim of this PhD thesis was to investigate the health effect in humans of dairy fat with different FA composition, produced from cows fed various amounts of green plant material (or roughage). A further aim was to create dietary scenarios with different quantities of dairy products included in order to elucidate the role of dairy products in overall nutrition and, further, to clarify the effect of dietary choices on GHGE.

In particular, the themes and studies in this thesis were divided into two parts, corresponding to the overall aims of the thesis. The first part is based on two dietary intervention studies in humans resulting in two original papers (**Paper I and II).** The second part is a theoretical study based on survey data from a representative sample of Danish adults and data on their associated GHGE (**Paper III).**

The following hypotheses were addressed:

- Consumption of dairy products from cows fed various amounts of green plant material reduces the risk of CVD and T2DM in humans compared to dairy products delivered from cows fed traditional grain based feed. Furthermore, these health beneficial effects of dairy products delivered from cows fed green feed are due to a natural high content of PA (**Paper I and II**).
- Dietary patterns without dairy products tend to be most beneficial in environmental terms. However, reducing or eliminating dairy product consumption lead to an insufficient supply of essential nutrition (**Paper III**).

Thesis outline

This thesis consists of an introductory part (*chapter 1*) and a theoretical background (*chapter 2*) including relevant areas for the thesis objectives. *Chapter 3* provides a general method description as well as the main results of the three studies. *Chapter 4* contains a general discussion of the three papers. In *chapter 5* the thesis is summarily concluded, while perspectives for future research are presented in *chapter 6.* Chapters 3, 4 and 5 are divided into part one (**paper I and II)** and part two (**paper III**) and presented and discussed separately.