Valorisation
In the studies described in this thesis we investigated whether thermogenic ingredients, such as capsaicin in red pepper and catechins in green tea, have beneficial anti-obesity effects as they may induce body weight loss via an increase in energy expenditure, a decrease in appetite and fat absorption or a change in gut microbial composition. The valorisation potential of these studies in terms of economic and societal relevance, and implication for specific target groups will be described.

Treatment of obesity is beneficial, as weight loss reduces the risk of mortality and morbidity in obese subjects. Even modest weight loss leads to beneficial health effects (1-3). The reason for developing obesity is a positive energy balance i.e. a higher energy intake than energy expenditure. In an environment that is in abundance of easy accessible and energy-dense nutrition, it is not easy to change the energy balance (4-6). Investigating these thermogenic food ingredients, which may produce reductions in absorption and appetite, and promote energy expenditure and fat oxidation, has considerable importance for anti-obesity therapy. Therefore, investigating whether capsaicin and catechin may be helpful in reducing energy intake and energy absorption, and increasing energy expenditure and fat oxidation, is relevant to support body weight loss. Obese and overweight people who are willing to lose body weight can benefit from thermogenic food ingredients. Red pepper and green tea are widely used in many parts of the world. Green tea is appreciated for its characteristic and fresh taste and red peppers are used in meals for their pungency and aroma. Both red pepper and green tea are especially common in Asian countries.

Normally, losing weight by reducing energy intake causes a reduction in energy expenditure and an increase in appetite. We found that capsaicin can contribute to the prevention of the yo-yo effect when entering negative energy balance, by sustaining energy expenditure and appetite profile at a similar level as in energy balance. Thus, our studies suggest positive benefits for individuals in negative energy balance, as occurs when dieting. However, we expect that long-term intake of capsaicin during weight loss is required to produce a beneficial effect of capsaicin on body weight. Furthermore, we suggest that capsaicin can be used to increase satiety and fullness in energy balance. Chili peppers belong to the family Solanaceae, genus Capsicum, and the pungency is due to the presence of capsaicinoids, which are components of peppers. Capsaicin, dihydrocapsaicin, norcapsaicin, nordihydrocapsaicin, homocapsaicin and homodihydrocapsaicin are capsaicinoids, and capsaicin is the major pungent component of hot peppers. There are numerous different peppers of the genus Capsicum, which all differ in size, shape, colour and pungency. The pungency of peppers is measured in Scoville Heat Units (SHU), which varies from plant to plant. For example bell pepper is 0 SHU, as it is not pungent at all, while cayenne pepper is 30,000–50,000 SHU. Both peppers are commonly used in a variety
of cuisines. The red pepper used in our studies was 39,050 SHU, which is comparable with cayenne pepper. We suggest that a dose of 3 grams of red pepper per day (39,050 SHU) has beneficial effects on the energy balance. Dieticians can communicate this recommendation concerning usage of capsaicin in combination with a weight loss program. At present several companies produce products that contain capsaicin, such as encapsulated and powdered red pepper. Also the fresh, dried and powdered hot chili peppers available in supermarkets contain capsaicin, but with these products it is more difficult to determine the exact dosage consumed. Chili peppers can be ingested directly or in capsule form, with oral exposure being more effective. Therefore to achieve the maximum effect, oral exposure is needed (7). However, for long-term use capsules can be useful, as several doses per day are needed to achieve the maximum effect and because not everybody will enjoy to have a pungent meal several times per day. Although frequent users of capsaicin report the oral pungency as less pungent, there are still people that do not like their meals to be spicy and pungent. Another option is to use capsinoid, the non-pungent capsaicin analog, and novamide, the less-pungent capsaicin analog, as they are also found to have beneficial effects on energy intake, appetite and energy expenditure. Since we found that the effects of capsaicin on fullness and energy expenditure in negative energy balance are even larger in combination with a high protein diet, we suggest to keep the level of protein intake at 0.8-1.2 g/kg/d as it usually is in energy balance, and to reduce the carbohydrate and fat intake during energy restriction. This can be achieved by using food products high in protein such as meat, fish, milk, cheese, eggs, beans and nuts or by supplementation of the diet with a powdered form of protein, such as in protein shakes. To save time and effort it should be considered whether there is need for the food industry to develop new products, such as high-protein shakes with added capsaicin or capsinoids.

Results from animal and human studies show that green tea catechin might be a very promising food ingredient in lowering body weight, increasing energy expenditure and decreasing fat absorption. Several studies found beneficial effects of green tea catechins on body weight loss and body weight maintenance after weight loss. However, in our studies we did not find beneficial effects of green tea catechins on resting energy expenditure, fat absorption and gut microbiota over the long-term in energy balance. An explanation for the lack of significant effects of long-term green supplementation in energy balance may be due to the nature of the intervention. We did observe the usual short term increases in diet-induced energy expenditure. Yet for a sustained effect over the day and over the long term, green tea catechins are recommended to be used together with an energy restriction diet, in order to sustain energy expenditure at the original level. Moreover the effects on energy expenditure and body weight loss seem to be larger in Asian than in Caucasian subjects. Asians have a higher frequency of the COMT<sup>th</sup> allele and Caucasians have nearly equal
frequencies of the COMT<sup>H</sup> allele and COMT<sup>L</sup> allele. We found that the effects of green tea catechins on energy expenditure and fat oxidation were stronger in subjects carrying the COMT<sup>H</sup> genotype. So, most likely the studies in Asians show larger effects as presumably most of these subjects carry the COMT<sup>H</sup> allele. Therefore, there may be ethnic differences in the response to green tea catechins with respect to the anti-obesity effects. Green tea is made from the fresh leaves of Camellia sinensis L. and contains 10-20% catechins. The main green tea catechins are epicatechin (EC), epigallocatechin gallate (EGCG), epicatechin (EGC), and epicatechin gallate (ECG), with EGCG being the most abundant catechin. Green tea, white tea, oolong tea and black tea are all made from the leaves of the Camellia sinensis L and all contain catechins. However, green tea and white tea contain most catechins, as they are less processed than oolong tea and black tea. Soil quality, leaf age and growing condition affect the amount of EGCG in tea, therefore it is important to choose a high quality tea. In general, tea leaves and tea powders contain more EGCG than tea bags. Optimal time seems to be about 3 to 4 minutes in water that has boiled, but is reduced to a temperature of 85 degrees Celsius. Do not drink tea with milk, as milk takes away some health benefits nor with sugar because of its calorific value. With respect to the dosage, most studies used between 200 and 700 mg EGCG per day, and in our studies we used 560 mg EGCG mg per day. Nevertheless, the optimum dose and composition (caffeine and catechins) is unknown and it is uncertain whether increasing dosage leads to greater effect. At present several companies produce products that contain green tea catechins, such as encapsulated green tea extract. However, the availability of high quality green tea can be improved, as it is difficult to find high quality tea in places outside Asia.

Capsaicin and catechins are naturally occurring components found in plant products, which will be safe when individuals will not exceed the dosages used in our studies. To conclude, thermogenic food ingredients appear to have small effects, depending on the target groups.
References

5. Raben A, Agerholm-Larsen L, Flint A, Holst JJ, Astrup A. Meals with similar energy densities but rich in protein, fat, carbohydrate, or alcohol have different effects on energy expenditure and substrate metabolism but not on appetite and energy intake. Am J Clin Nutr 2003;77:91-100.