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DISSERTATION

Titel der Dissertation

"Evaluation and improvement of the nutritional quality of European ready meals"

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For my dearest children Sarah and Florian

ABSTRACT

Convenience foods and ready meals play a substantial role in today´s food consumption patterns and their importance is predicted to increase even further. This trend is caused mostly by the feeling of time scarcity, the growing number of small- and single-households, more working women, variable family eating times, and the lack of cooking skills or dislike of cooking. This is in spite of the fact that in consumers´ minds ready meals are associated with poor taste and low nutritional value. Recently, plausible hints for an association between a higher consumption of ready meals and an increased probability of weight gain were found. Additionally, there are studies confirming that the salt contents of various convenience foods, including ready meals, are strongly varying and for most products alarmingly high. Surprisingly so far only very few research activities have been published on the overall nutritional quality of ready meals.

Therefore, the aim of the present study was *1)* to laboratory analyse ready meals on their energy, macronutrients, sugars, fatty acids and salt, *2)* to identify nutritional imbalances and *3)* to develop nutritionally improved ready meals in cooperation with partners from the food industry. The study was performed within the EU-funded project "Double Fresh" (grant number FOOD-CT-2006-23182). Thirty-two chilled, frozen and heat-treated ready meals (only main dishes) from six continental European countries were analysed. After proposing understandable guidelines to the food industry to improve the nutritional quality, seven optimised ready meals were created and also analysed. Additionally, a comprehensive survey of convenience meals from the Austrian market (*n*=572) was conducted to evaluate the salt contents of a wider product range.

In summary, the results indicate that half of the ready meals were nutritionally imbalanced by providing elevated fat (>30% of energy) and low carbohydrate levels (<50% of energy). Since half of the meals contained too much saturated fatty acids (>10% of energy), the fat quality was also not recommendable. The

study further proves that the salt contents of the analysed ready meals and the surveyed Austrian convenience foods mostly exceed the targeted intake levels for one meal (30% of RDIs) and some even the daily recommended dose. The results clearly demonstrate that the ready meals´ nutritional quality can be improved considerably with the addition of vegetables, the use of sauces with less added sugar, lard, butter, cheese or other high-fat milk products and the preference of lean cuts of meat, fatty fish and vegetable oils instead of high-fat meat parts and animal fats.

One newly developed ready meal – a vegetarian pasta dish with tomato sauce, cheese, spinach and pine nuts – met the dietary recommendations and thus can be defined as a “healthy” ready meal. Since the salt content of the newly developed ready meals was also significantly lower, the data of this study support the fact that a stepwise reduction of the ready meals´ salt content by meal reformulation is not only necessary, but also achievable without compromising the sensory quality and the products´ shelf life.

Since ready meals are likely to be part of the diet now and in future, more effort is needed to create and offer consumers a wider range of tasty, affordable and healthy ready meals. This would give consumers the possibility to choose and, if they prefer at least sometimes the healthier options, this would have an impact on their health.

ZUSAMMENFASSUNG

Halbfertig- und Fertiggerichte spielen eine wesentliche Rolle in der heutigen Ernährung und ihre Bedeutung dürfte in den nächsten Jahren weiter ansteigen. Faktoren wie Zeitmangel, die steigende Zahl von Klein- und Single-Haushalten, mehr weibliche Arbeitskräfte, unterschiedliche Essenszeiten innerhalb der Familie und die Abnahme von Kochfertigkeiten werden für diese Entwicklung verantwortlich gemacht. Dieser Trend wird trotz der Tatsache, dass Fertiggerichte für Konsumenten einen schlechteren Geschmack und eine niedrigere Nährstoffqualität haben als selbst zubereitete Gerichte, weiter anhalten. Kürzlich wurden Hinweise für einen Zusammenhang zwischen einem höheren Konsum von Fertiggerichten und einer erhöhten Wahrscheinlichkeit einer Körpergewichtszunahme gefunden. Außerdem bestätigen etliche Studien, dass die Salzgehalte von vielen industriell verarbeiteten Lebensmitteln, unter anderem auch von Halbfertig- und Fertiggerichten, sehr starken Schwankungen unterliegen und zumindest teilweise alarmierend hoch sind. Trotzdem wurden bis heute noch sehr wenige wissenschaftliche Studien in Bezug auf die ernährungsphysiologische Qualität von Fertiggerichten durchgeführt.

Deshalb war das Ziel der vorliegenden Arbeit *1)* Fertiggerichte auf ihren Gehalt an Energie, Makronährstoffen, Zucker, Fettsäuren und Salz zu untersuchen, *2)* Schwachstellen in der Nährstoffzusammensetzung zu identifizieren und *3)* aus ernährungsphysiologischer Sicht verbesserte Fertiggerichte in Zusammenarbeit mit Unternehmen der Lebensmittelindustrie zu entwickeln. Die Studie wurde im Rahmen des von der EU finanzierten Projekts „Double Fresh“ (Projektnummer FOOD-CT-2006-23182) durchgeführt. Zweiunddreißig gekühlte, tiefgekühlte oder durch Erhitzung haltbar gemachte Fertiggerichte (nur Hauptgerichte) aus sechs europäischen Ländern wurden auf die oben genannten Parameter analysiert. Nachdem Richtlinien zur Optimierung der ernährungsphysiologischen Qualität für die Lebensmittelindustrie erstellt wurden, wurden darauf basierend sieben neue Gerichte entwickelt und ebenfalls analysiert. Zusätzlich wurde eine umfas-

sende Erhebung von Fertiggerichten des österreichischen Marktes (*n*=572) durchgeführt um den Salzgehalt einer größeren Produktgruppe beurteilen zu können.

Die Hälfte der analysierten Fertiggerichte hatten zu hohe Fett- und zu niedrige Kohlenhydratgehalte (bei Fett >30% und bei Kohlenhydraten <50% der enthaltenen Energie). Die Fettqualität der Gerichte war ebenfalls nicht empfehlenswert, da die Hälfte der Gerichte auch zu viele gesättigte Fettsäuren enthielten (>10% der Energie). Außerdem konnte bestätigt werden, dass die Salzgehalte sowohl der im Labor untersuchten als auch der erhobenen Fertiggerichte zum Großteil über den empfohlenen Aufnahmemengen für eine Mahlzeit (=30% der Empfehlung) und bei manchen Gerichten sogar über der täglich empfohlenen Menge liegen. Die Ergebnisse zeigten jedoch eindeutig, dass die ernährungsphysiologische Qualität durch die Zugabe von Gemüse, die Bevorzugung von magerem Fleisch, fettreichem Fisch und pflanzlichen Ölen und die Verwendung von Saucen mit wenig zugesetztem Zucker, Schmalz, Butter, Käse oder anderen fettreichen Milchprodukten deutlich verbessert werden kann.

Ein neu entwickeltes Gericht – ein vegetarisches Nudelgericht mit Tomatensauce, Käse, Spinat und Pinienkernen – entsprach den Nährstoffempfehlungen und kann daher als „gesundes“ Fertiggericht bezeichnet werden. Da der Salzgehalt der neu entwickelten Gerichte signifikant niedriger war, unterstützen die Ergebnisse die Tatsache, dass eine schrittweise Salzreduktion bei Fertiggerichten nicht nur notwendig, sondern auch möglich ist ohne die sensorische Qualität und die Haltbarkeit zu beeinträchtigen.

Da Fertiggerichte auch in den nächsten Jahren Teil der Ernährung sein werden, sollten größere Anstrengungen unternommen werden, um Konsumenten eine breitere Auswahl an wohl schmeckenden, leistbaren und gesunden Fertiggerichten anbieten zu können. Dies würde den Konsumenten eine Auswahl ermöglichen und falls sie zumindest gelegentlich die gesünderen Alternativen wählen, hätte dies auch einen Einfluss auf ihre Gesundheit.

PUBLICATIONS

The present thesis is based on the following scientific articles:

Paper I

KANZLER S., MANSCHEIN M., LAMMER G. & WAGNER K-H. (2015). The nutrient composition of European ready meals: Protein, fat, total carbohydrates and energy. *Food Chemistry* **172***,* pp. 190-196.

Paper II

KANZLER S., HARTMANN C., GRUBER A., LAMMER G. & WAGNER K-H. (2014). Salt as a public health challenge in continental European convenience and ready meals. *Public Health Nutrition* **17***,* pp. 2459-2466.

Additionally, a major focus of the thesis was to disseminate the results to ready-meal manufacturers and retailers. Thus, the following trade journal publications emerged as part of the thesis:

Trade journal publication I

KANZLER S. & WAGNER K-H. (2009). Guidelines for the improvement of the nutritional quality of ready meals in Europe. *Ernährung/Nutrition* **33**, pp. 13-15.

Trade journal publication II

KANZLER S. & WAGNER K-H. (2009). Optimierung der Komponenten – Verbesserung der ernährungsphysiologischen Qualität von Fertiggerichten. *Lebensmitteltechnik* **9**, pp. 45-47.

Trade journal publication III

KANZLER S. & WAGNER K-H. (2009). Ernährungswissenschaftler verbessern Fertiggerichte. *Tiefkühlreport* **7-8**, pp. 40-41.

Reprints and accepted papers were published with kind permission of the respective publishers.

A list of further publications as well as oral and poster presentations can be found on page 84.

CONTENTS

ABBREVIATIONS

ANOVA	One-way analysis of variance
ASE	Accelerated solvent extraction
CHD	Coronary heart disease
CHO	Carbohydrates
CVDs	Cardiovascular diseases
DALYs	Disability-adjusted life-years
DGF	German Society of Fat Science
DHA	Docosahexaenoic acid
%E	Percentage of energy intake
EPA	Eicosapentaenoic acid
et al.	et alii (and others)
e.g.	exempli gratia (for example)
EU	European Union
F	Female
GC-FID	Gas chromatograph with flame ionisation detector
HBSC survey	Health Behaviour in School-aged children survey
i.e.	id est (that is)
M	Male
max	Maxima
min	Minima
MUFAs	Monounsaturated fatty acids
NADPH	Nicotinamide adenine dinucleotide phosphate
NCDs	Non-communicable diseases
PAL	Physical activity level
PUFAs	Polyunsaturated fatty acids
RDIs	Dietary recommendations
RSD	Relative standard deviation
SFAs	Saturated fatty acids

TFAs	Trans fatty acids
UK	United Kingdom
U.S./USA	United States of America
vs.	versus
v/v	volume/volume
WHO	World Health Organisation
w/w	weight/weight

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SUPPLEMENTAL TABLES

1 INTRODUCTION

1.1 The importance of convenience foods and ready meals in today´s society

Over the past years, the demand for convenience foods and ready meals has been growing steadily. Driven mainly by convenience, more and more consumers prefer the easy-to-prepare ready meals to traditional cooking.

According to an online AC Nielsen consumer survey conducted in 2006 54% of Europeans are consuming ready meals occasionally or even frequently. The same is true for Austria as well as for many other European countries, such as Belgium, Germany, Finland or Norway, where those polled showed the same consumption frequencies (48-53%). The highest consumption rate was found for the UK with 62% of the included sample population [(1)]. More recent data on the ready meal consumption for the European region are not available.

This trend is further reflected by the high market share, the increasing sales data and more sales floors for ready meals at the retailers. In Austria in the year 2007 the sales value of ready meals reached 226 million Euros with a retail volume of 32 000 tonnes. The category “frozen ready meals” was, with about 98 million Euros, the subsector with the highest sales value [(2)]. Since the convenience trend still prevails, the value of the ready meal market experienced a growth of 2% in 2012. This competitive market is led by the three main players Dr. Oetker, Rewe and Iglo Austria. The success of Dr. Oetker is based on the two popular frozen pizza brands Ristorante and Pietro Pizzi. Rewe, with its brand Chef Menü, is the market leader for chilled ready meals and chilled pizza. Iglo Austria, on the other hand, is the leader for frozen ready meals [(3)].

As ready meals are not considered to be healthy and in Austria a health and wellness trend (besides the convenience trend) is observed, the ready meal market is forecasted to grow only slightly in the following years up to a sales value of 285 million Euros in 2017 [(3)].

1.1.1 Socio-demographic and economic evolutions triggering the convenience trend

Major reasons for the convenience trend are several socio-demographic and economic changes, as the growing number of small- and single-households, more working women, variable family eating times, and the feeling time is scare [4; 5].

1.1.1.1 *Changing household structures*

The change in household structures with more small-households (mainly single-person households and households with couples) can also be observed in Austria. In the year 1985 in 27.4% of all households (768 000) only one adult was living, whereas in the year 2012 the same was true for already 36.5% of all households (1 341 100). The number of couples without children (living in the same household) has also been steadily increased (1985: 597 000; 2012: 872 000) [6]. These changes can be further confirmed by the decreasing average size of households (1985: 2.67 persons per household; 2012: 2.27 persons) [7]. Reasons are on the one hand the trend for living in smaller households, but on the other hand also the changes in the age distribution reflecting a growing number of older people in today´s society [6]. An overview of the different household structures found in Austria in 2012 is shown in Figure 1.

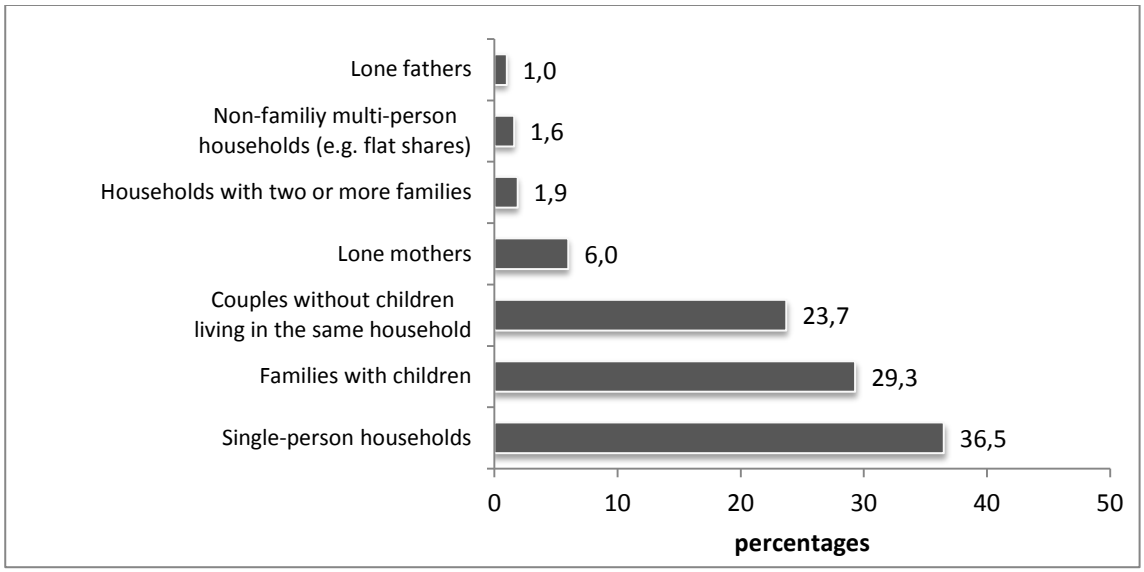

Figure 1. Contribution of different household structures in Austria in the year 2012; Modified after Statistik Austria, 2013 [6]

According to forecasts this trend will continue in the following years. The persons living alone will increase above average. In Austria it is expected that in 2030 1.56 millions will live in single-households compared to 1.33 millions in 2011 (increase by +17.4%). Major reasons are the individualisation and the demographic ageing which both leads to a higher number of people living alone [8].

1.1.1.2 *Increased female participation in the workforce*

In Austria as well as in other industrialised countries an increased labour participation of women on the employment market has been observed in the last decades. Within the last ten years the employment rates for 15 to 64 year old women increased from 61.2% (2002: 1 644 700) to 67.3% (2012: 1 914 400), whereas the employment rates for men were constant, but on a higher level (2002: 76.4% or 2 066 800; 2012: 77.8% or 2 195 100) [9]. Figure 2 illustrates the trend for more middle-aged working women between the years 1951 and 2011.

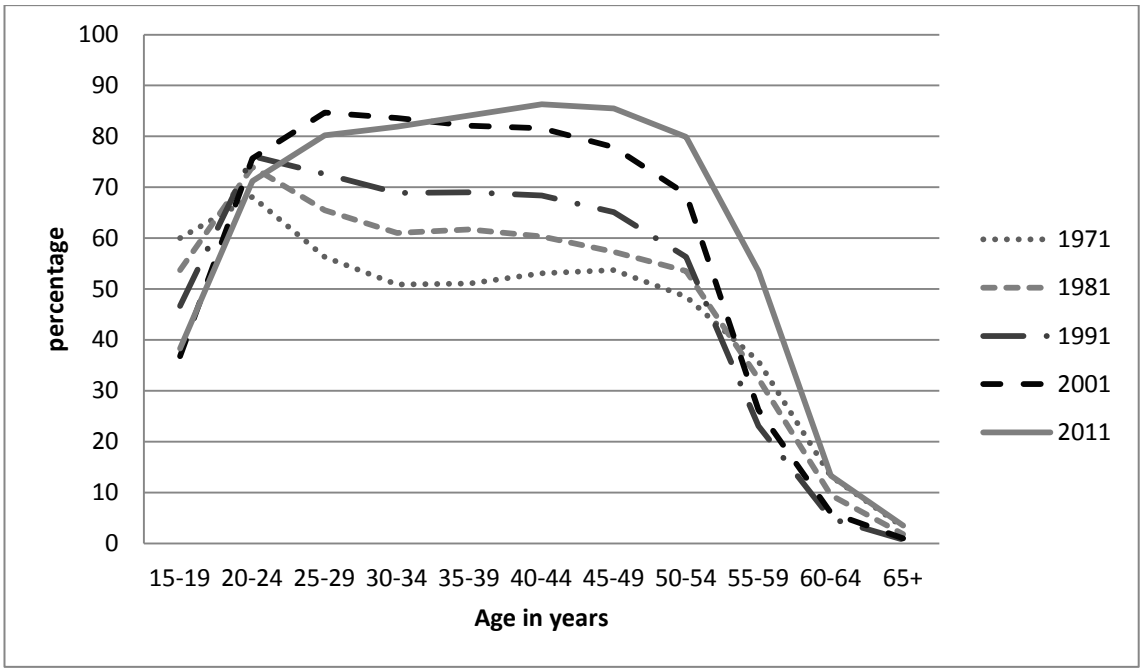

Figure 2. Development of employment rates for women from 1971 to 2011; Modified after Statistik Austria, 2013 [10]

The employment rates will grow further until 2050. This growing is expected to be based mainly on a further increasing number of female employees while the number of male employees will increase only slightly [11]. The predicted increase of female employment rates until 2050 is shown in Figure 3.

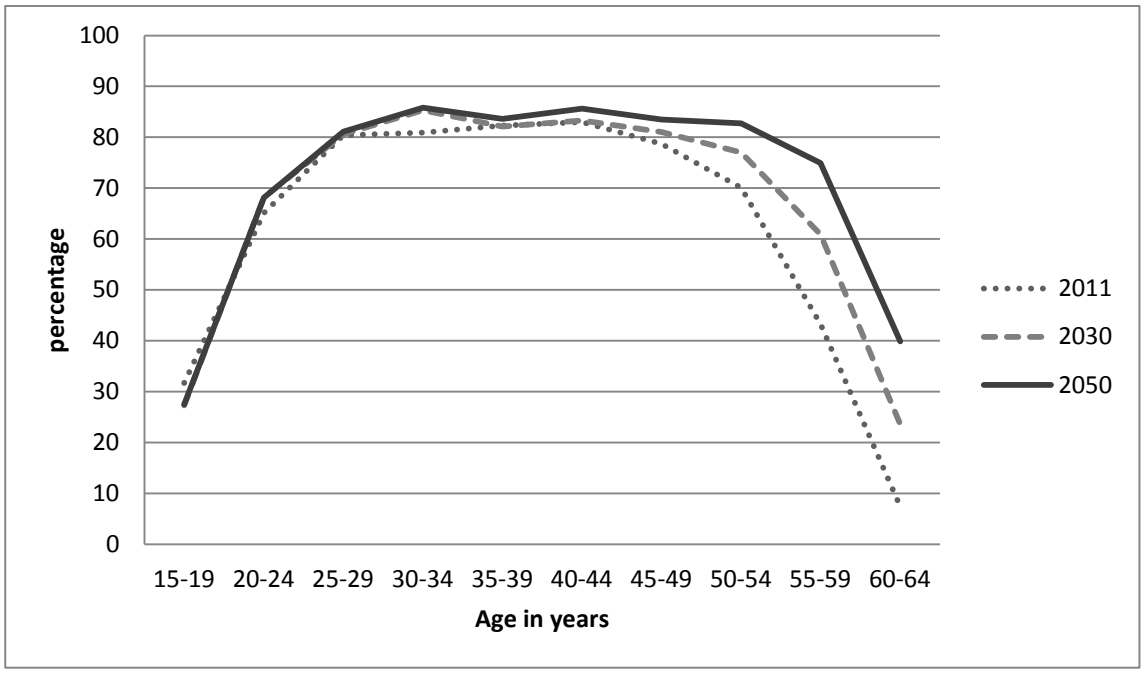

Figure 3. Predicted employment rates for women from 2011 to 2050; Modified after Statistik Austria, 2013 [11]

1.1.2 Influence of time scarcity on food choices

Time scarcity describes the feeling of not having enough time to do everything one needs or wants to [12]. These feelings are widespread today, mainly caused by the fact that both men and women are working. Thus, in the evenings, they have to eat, do housework, stay in contact with friends and/or family, find time to relax and as parents they have to care about their children [5]. Managing all these tasks is especially difficult for single-parents who cannot share responsibilities [5] or for families in poverty who cannot afford eating at a restaurant or paying someone for support (e.g. a cleaner) [13]. Since the amount of time spent for eating can vary from hours when a home-cooked meal is eaten sitting at a table to minutes when the meal is bought at a fast food res-

taurant and eaten while driving, the feeling of time scarcity influences food consumption patterns. Many people try to reduce time performing household tasks, including cooking, which led to a decrease in family meals [5; 14]. The answer of the food industry to this trend was the introduction of convenience foods on the market, from the so-called TV dinners in the 1950s to the wide range of ready meals today [15]. Several studies found that perceived time pressures, role overload, different eating times of family members and unpredictable routines are positively contributing to the frequency of ready meal consumption and the use of convenience products [4; 16-18], since these meals can be prepared or eaten in less time at different times and places [5; 14].

For working mothers, for instance, feeding their children is an important priority, but since they often feel time-pressured, they find different ways to fulfil this task. Mothers, who prioritise eating a home-cooked meal together with their children, take time for cooking. Most mothers, however, prefer to prepare a meal as quickly as possible, so that they can use their time for other responsibilities or priorities. Household support from other family members, flexible work schedules, less working hours, coming home earlier, cooking skills and self-efficacy are factors which enable women to prepare a home-cooked meal. It is more difficult for single-parents and for mothers with inflexible working hours. Most mothers are recognising the fact that convenience foods or fast foods may be not the healthiest choice, but these products help them to feed their children in their available time [19].

The use of convenience products (such as e.g. stir-fry sauces and meal base powders) enable women under time pressure or with unpredictable daily routines to prepare a meal, which is for them perceived as a “quick, tasty and healthy meal” consistent with their ideals in less time and with less effort [16].

For most people time-scarcity is not only a barrier to prepare a home-cooked meal, it is also a barrier to a healthy lifestyle including physical activity and eating healthy foods [20].

1.1.3 Drivers for convenience consumption

1.1.3.1 *Socio-demographic and social factors*

Age, gender, household size, having children and working status were identified to be predictors for the intention to purchase convenience foods. Older people consume less convenience products than younger ones and women less than men. This is probably caused by the fact that older people are used to prepare their meals from scratch, since ready meals were not available when they grew up [21]. Convenience products turned out to be used more frequently in single-person than in multi-person households, and are more common among single men than women. Households with living-at-home children are more likely to buy unprocessed and fresh foods and to spend more time with preparing a home-cooked meal [22].

Social factors also influence the demand for these products. For instance, TV dinners are eaten more frequently alone than together with family or with friends [18].

1.1.3.2 *Cooking skills and cooking enjoyment*

In recent studies cooking skills are found to be another strong predictor for ready meal consumption. Having fewer cooking skills is increasing the likelihood to consume ready meals [21; 23]. This association was observed mainly for highly and moderately processed food items, which is probably caused by the fact that these foods are more difficult to prepare from scratch for a person lacking cooking skills than single meal components or salads [21]. Van der Horst et *al.* [23] concluded that both lack of time and lack of cooking skills might be barriers for preparing healthy home-made meals [23].

That a lack of confidence in the own cooking ability influences food provisioning strategies was also shown by Bava et *al.* [16]. Women who did not help their mothers with cooking as children and who do not like experimenting in the kitchen, because they are afraid of failure, use some pre-prepared meal components (e.g. instant gravies) as “fail-proof” options. Interestingly, the lack of confidence in the own cooking ability did not increase the consumption of completely pre-prepared ready meals, because these foods are not in line with their preferred food provisioning practices [16].

High self-efficacy related to meal management is linked with food provisioning strategies which enable to prepare meals at home, such as planning a menu for a week, preparing shopping lists for the grocery store, being able to cook a healthy meal with only few available ingredients and preparing meals in advance. Low self-efficacy, however, is associated with a higher use of convenience foods and eating more frequently at fast food restaurants [24].

Besides cooking skills, the cooking enjoyment is related to the consumption of convenience foods. A lower interest in cooking is associated with a higher intention to purchase ready meals [4; 17].

A higher cooking enjoyment is further associated with higher cooking skills, especially for men. Women have higher cooking skills than men, in all age groups. Higher cooking skills led to a higher weekly vegetable consumption and to a less frequent use of convenience foods. Therefore, it may be easier for people with cooking skills to meet nutritional guidelines and to make healthier food choices, because cooking enables them to choose between self-prepared and pre-prepared meals [25].

1.1.3.3 *Moral attitude and beliefs about ready meals*

In consumers´ minds ready meals are associated with poor taste and poor nutritional value (fatty/salty). Thus, the decision to consume ready meals instead of home-cooked meals is based on a trade-off between convenience aspects, on the one hand, and sensory- and health-related aspects on the other hand [26]. Concerns about naturalness and freshness of foods and nutrition knowledge are negatively contributing to the consumption of convenience foods. The consumption of convenience products decreases with a higher concern of the naturalness or freshness of food and a more consolidated knowledge of nutrition [4; 21].

Since the convenience associated with ready meal consumption causes feelings of guilt, regret and neglecting one´s duty, using these meals may become very undesirable for some people. However, preparing a home-cooked meal evokes positive feelings. This contrast is explainable by the fact that consumers still belief their meals should be prepared with an appropriate amount of time, effort and attention [26].

That moral attitude has to be included for explaining the consumption of ready meals was confirmed by a recent study from Olsen et *al.* [27]. The consumers in this study stated that ready meals "make life easier", but they do not "give life more meaning". This confirms that consuming these meals is still associated with a negative feeling of doing the morally wrong thing [27].

Several studies concluded that consumers who purchase more convenience foods and ready meals have different beliefs and attitudes towards these products than consumers who purchase them in a lesser amount [4; 28-30]. Users of ready meals have in common that they feel time-pressured with high stress levels and for them convenience foods are a possibility to save time and effort [4; 28]. Compared to other consumers, who purchase only few convenience foods, users perceive these meals also to be healthier [4], a good value for money [4; 28; 30] and a good backup to have in the home [28; 30]. The association between having more positive beliefs about the healthiness of ready meals and a higher intake has been confirmed by a recent study from Van der Horst et *al.* [23].

1.1.3.4 *Time- and effort-related factors*

Although convenience products by definition minimize time and effort, in a recent study by Brunner et *al.* [21], variables related to time and effort did not predict their consumption. The authors concluded that today convenience foods are used by everybody once in a while to make life easier even without time pressure. This is in line with a study from Carrigan et *al.* [31]. They stated that for mothers in the UK the use of convenience foods made cooking easier and quicker and the use of these products led to "reinterpreted versions of home-made meals". The use of convenience foods may be against some of their food provisioning ideals, but the products offer the mothers the possibility to feed their children the best way possible in their circumstances [31]. Both studies stated that convenience foods nowadays play an important role in daily life [21; 31], and are chosen as time-management strategy [22]. Thus, the use of these products influences food preparation and kitchen habits, but they have hardly any impact on individuals´ table habits [22].

When contradictions, such as concerns about naturalness or nutrition knowledge occur, then convenience foods are avoided. Hence, the contradictions are the variables which predict the use of convenience foods and ready meals and not the time- and effort-related factors [21].

1.1.4 Definition of convenience foods and ready meals

According to Traub and Odland [32] convenience foods are defined as "any fully or partially prepared foods in which significant preparation time, culinary skills or energy inputs have been transferred from the home kitchen to the food processor and distributor". This definition, for instance, includes ready meals, fast foods, and meals from restaurants, canteens or takeaways.

Since the diversity of production and distribution solutions of convenience foods are increasing, a more detailed classification system is needed. The one introduced by Costa et *al.* [33] is shown in Figure 4.

Home-meal replacements, which include ready meals, are defined as "meal solutions that have been produced away from home for in-house consumption" [33]. These meals can either be purchased at retailers or takeaway shops or supplied by home delivery systems. In case of ready meals they are meal solutions which are produced by food manufacturers [33].

Important aspects for meals to be classified as home-meal replacements are that:

- They are ready for consumption with only minimal preparation steps.
- They include all components of the meal (a protein, a carbohydrate and a vegetable source).
- They are regarded as the meal´s main dish by consumers.

Snacks, starters, salads or soups can also be considered as home-meal replacements [33].

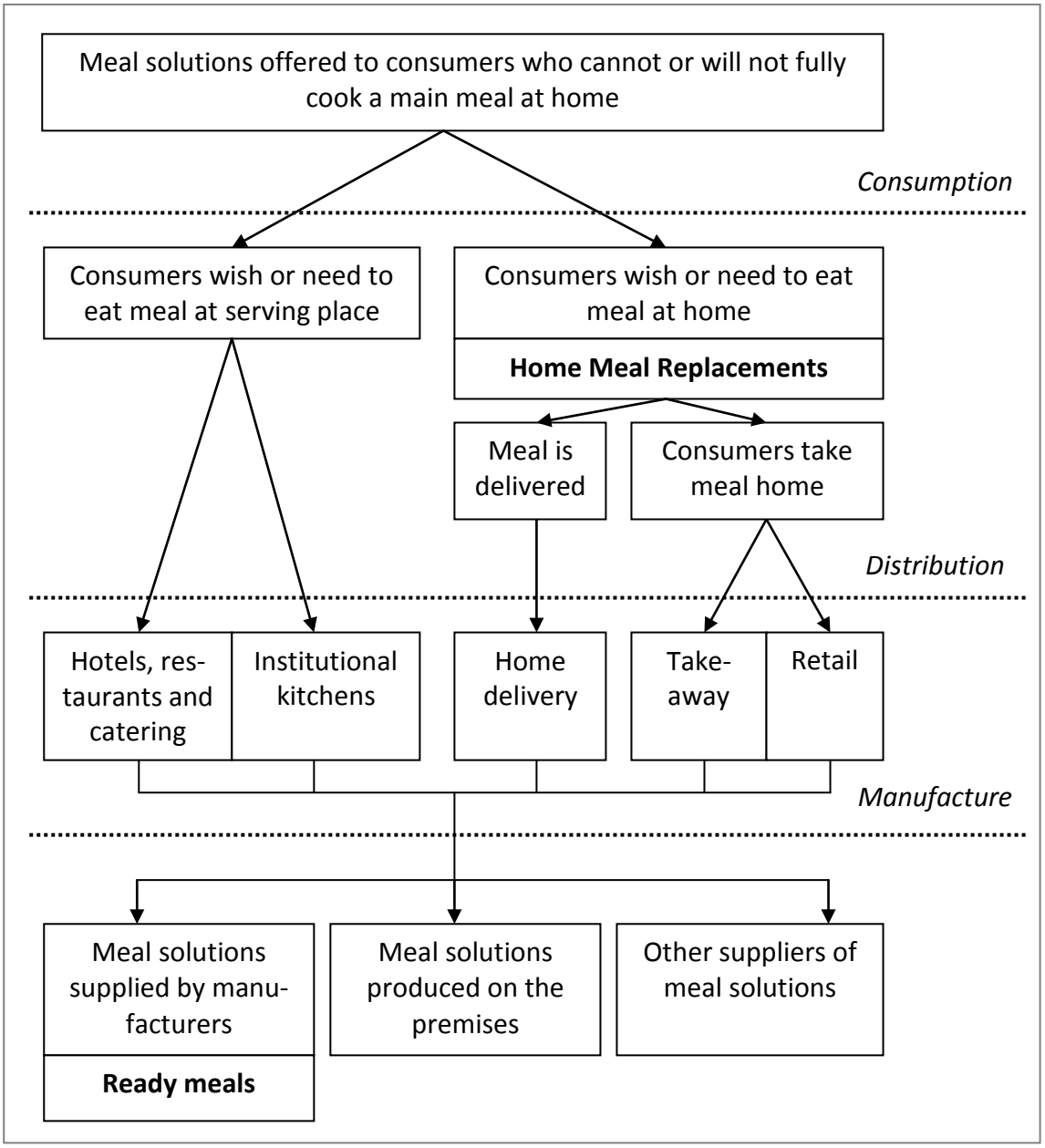

Figure 4. Categories of meal solutions and its terminology; Modified after Costa et *al.*, 2001 [33]

In a recent publication Scholliers distinguished between two groups of convenience foods, which are "the full meal" and "convenience compounds that are used for pre-paring a meal" [34]. To a ready meal in term of a full convenience meal "the housewife did not have to add anything to the product – unless she wanted to" [35].

Besides fresh prepared ready meals, which only had to be consumed (e.g. meals for takeaway), most ready meals are preserved either by drying, heating (pasteurisation or sterilisation), freezing or cooling [36]. Typical dried products are packet soups or instant products such as pasta dishes. For these the addition of water prior heating is important. Regarding pasteurised or sterilised products the first examples on the market were various pre-prepared foods in tins (canned foods). Nowadays by heating preserved meals are also offered in other packages, for instance in plastic trays.

The newest preservation techniques are freezing and chilling, which were both associated with the invention of the refrigerator. In the U.S. the refrigerator was found in nearly all kitchens already in the 1930s, whereas in Austria this was not the case until the economic recovery in the 1950s. In the year 1958 20% of all Austrian households had a refrigerator, in the mid nineteen-sixties the market saturation was 60% and ten years later it was 95% [37; 38].

1.1.5 Short insight in the history of pre-prepared meals

The beginning of preserving foods by heating under exclusion of air, which is the concept of canned foods, is dated in the first 19th century. In 1809, for instance, a patent was granted to the French cook Nicolas Appert for the production of canned foods in glasses. One year later in the U.K. Augustes de Heine and Peter Durand invented the first tin made of tinplate [39]. Such a package was used 1897 in the U.S. by John T. Dorrance, the chemist at the Campbell Soup Company, to create the first condensed canned soups in five varieties, including Tomato soup. This product remains popular in the U.S. until now [40]. At that time in Germany canned foods were only used for soldiers and as luxury products for people, who could afford. In 1910 a 1.5 litre tin with string beans had a price of 37.5 cents, while a hundred of fresh string beans could be purchased for only 20 to 25 cents. However, their popularity grew amongst the bourgeoisie, since they were non-perishable [41]. After World War One the fasting German population was supported with canned foods as relief supplies. Since then canned foods were associated with emergency foods [39]. In the 1950s tinned vegetables and

fruits became more popular, especially tropical fruits (e.g. pineapples) and thus higher sales volumes were found [42].

The industrial production of dried food products in Central Europe started in the mid 19th century [39]. 1884 Julius Maggi was the first who produced a protein-rich legume powder, which was the basis for affordable soups. Then he marketed a range of ready-to-cook soups made of different dried vegetables [43]. The famous Maggi seasoning sauce ("Maggi Würze") was developed in 1886 [44]. At the same time the company Knorr in Germany and Austria started to manufacture the so-called "Erbswurst", a traditional instant pea soup which was sold as a concentrated paste [45]. From the 1950s on both companies produced packet soups instead of the dried soups packaged as rolls or cubes [39]. These kind of dried soups are still available at the market. 1973 the first "Maggi Fix" products, which are dried mixtures of all necessary ingredients to cook typical Austrian meals (e.g. goulash or pasta asciutta), were developed and until now successfully placed at the market [46].

In 1954 the history of frozen ready meals started in the U.S. when the Swanson Company launched their so-called "TV dinners". The first one was turkey with buttered peas, sweet potatoes and sauce [47]. These meals were packaged in trays made of aluminium with all necessary ingredients and only had to be heated in the oven. They already met the above presented definition from Costa et *al.* [33]. The TV dinners were the response of the industry to people´s desire to prepare meals in less time, and their wish to do something else while eating, such as watching TV [5]. In the year 1987 after the invention of the microwave oven the packages were changed to plastic trays instead of the original aluminium trays [47].

In Austria frozen foods gained access to the market not before the 1960s. The first popular products were poultry and vegetables, especially spinach and some years later fish fingers. At the end of 1970s, the same time when the first microwave ovens were placed in the kitchens, companies started to offer frozen ready meals [42]. On the contrary to canned foods, frozen foods started with a positive image, because they benefited from the prestige of the newly invented refrigerator. They were strongly associated with the imagination of fresh products [39].

Today frozen and chilled ready meals are still more popular than canned and dried ready meals which can be confirmed by the market sales volumes. For instance, in 2007 10900 tonnes frozen, 5500 tonnes chilled, 2600 tonnes canned and only 200 tonnes of dried ready meals were sold in Austria [(2)].

1.1.6 The Austrian ready meal market

During the time of this thesis a comprehensive market survey as pre-study was conducted. The first survey was carried out between October 2007 and January 2008 at eleven retailers, whereby the included commercial chains covered about 90% of the Austrian food retail trades. In total data on food type, preservation technique, producing company, package material, package size, portion size and price were gathered from 1751 convenience foods [(48)].

277 different trademarks were offered to the consumers on the Austrian market, but there were only 8 brands with an individual product share greater than 2.5% from all included convenience products (e.g. Iglo, Knorr, Maggi, Chef Menü, Spar Feine Küche). Regarding the food type most convenience products were pasta dishes followed by soups and pizzas (see Figure 5) [(48)].

As preservation technique for 35% of all meals freezing was used, for 25% chilling, for 20% drying and for 15% pasteurisation or sterilisation. 5% of all meals were offered freshly prepared and chilled [(48)]. Hence, our data support the above mentioned fact that in Austria frozen and chilled products are more popular than products preserved by heating or drying. The main packaging materials used were plastic and cardboards. About three-quarters of all evaluated meals were offered as single-portion meals. 85% of all meals contained a nutritional labelling (thereof 23% “Big Eight” and 62% “Big Four”) [(48)].

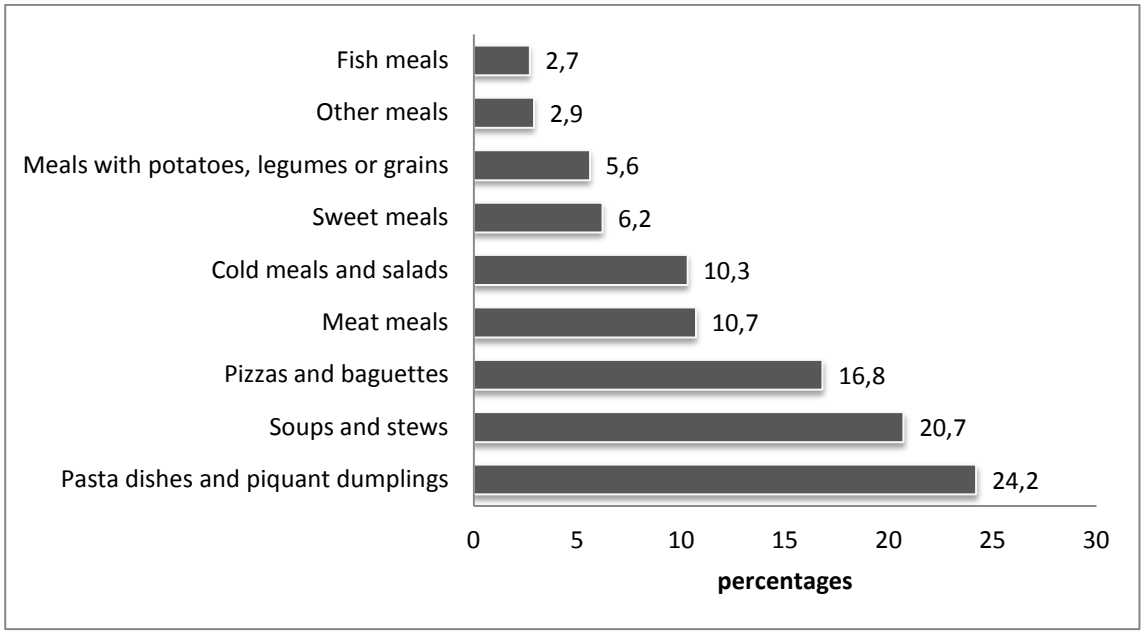

Figure 5. Distribution (%) of all sampled ready meals (*n* = 1751) from the Austrian market in the years 2007 and 2008 according to different meal type categories; Modified after Leimgruber, 2008 [48]

1.2 Dietary factors and their influence on human health

The leading causes of death in nearly all countries worldwide are non-communicable diseases (NCDs), such as cardiovascular diseases (CVDs), cancers, chronic respiratory diseases and diabetes [49]. In 2009 NCDs were responsible for about 80% of all deaths in Europe [50]. To reduce the burden of morbidity, mortality and disability due to NCDs is one of the greatest public health challenges in the 21st century. The World Health Organisation agreed on 9 global voluntary targets to prevent NCDs. These targets include amongst others, to stop the rise of diabetes and overweight, the reduction in the mean population sodium or salt intake, and, the reduction in the prevalence of raised blood pressure [51; 52].

1.2.1 Overweight and obesity

Worldwide, the prevalence of overweight and obesity has more than doubled since the 1980s. Overall in 2014, 39% of the world´s adult population (38% of men and 40% of

women) were overweight and 13% (11% of men and 15% of women) were obese [53]. In Germany, according to the National Nutrition Survey II, the prevalence for overweight (37%) and obesity (21%) was approximately in the same range [54]. Data for Austrian adults showed that 28% were overweight (37% of men and 18% of women) and 12% were obese (15% of men and 10% of women) [55].

Results from the Health Behaviour in School-aged Children (HBSC) survey from 2009/2010 indicated that the prevalence of overweight including obesity in European 11- to -15-year-olds ranged from 5% to more than 25% [56]. For German children aged from 3 to 17 years a prevalence of 15% for overweight and 6% for obesity was observed [57]. Data for Austrian children between 7 and 14 years of age were comparable with the ones from Germany (17% overweight and 7% obese) [55]. Children with a lower socioeconomic status, a migration background or an overweight mother have a higher risk for being overweight than others [57].

As already mentioned above, overweight and obesity are not only associated with various physical inabilities and psychological problems, they are also major risk factors for the development of NCDs, such as CVD (mainly heart disease and stroke), some cancers (endometrial, breast, and colon), musculoskeletal disorders (especially osteoarthritis) and diabetes [53]. In 2010, overweight and obesity were estimated to cause 3.4 million deaths, 4% of years of life lost, and 4% of disability-adjusted life-years (DALYs) worldwide [58].

The fundamental cause of obesity and overweight is an energy imbalance between energy intake and energy expenditure over a considerable amount of time. The main nutrients delivering energy are fat, carbohydrates and protein. Globally, there has been, on the one hand, an increased intake of energy-dense foods rich in fat and sugars, and, on the other hand, a decrease in physical activity due to a sedentary lifestyle caused by changed working conditions, transportation systems and urbanisation [59]. In most European countries the fat intake is higher than recommended and in general, the fatty acid pattern did not meet the recommendations as well [60].

Besides nutrition, physical inactivity has to be considered as important risk factor for overweight. With regular physical activity not only overweight can be prevented [53],

but also the risk of NCDs, such as heart disease, stroke, diabetes, and breast and colon cancer can be reduced [52]. Thus, the World Health Organisation recommends a minimum of moderate-intensity physical activity of 60 minutes per day for children and 150 minutes per week for adults. To increase the amount of physical activity several high-income countries have already implemented national exercise promotion programmes [52].

Though overweight is preventable [53], until today the numbers of those affected are rising [61] and no country succeeded in implementing an effective public health strategy to stop or even reverse this trend [62].

1.2.2 High sodium or salt intake

There is conclusive evidence that a high salt intake is associated with hypertension, which consequently increases the risk for CVDs [63-65]. Globally, 1.7 million deaths per year caused by CVDs have been attributed to excess sodium intake [52]. To reduce blood pressure a limited salt intake is recommended and for adults should not exceed 6 g/day according to different expert committees [64; 66-69] or 5 g/day according to the World Health Organisation [65].

The cost-effectiveness of salt reduction programmes to reach these intake levels and to prevent CVDs has been demonstrated recently [70-74]. A saving of $US 10-24 billion in annual health-care costs with a population-wide reduced salt intake of 3 g/day has been estimated [71]. According to the World Health Organisation, “a reduced salt intake and salt content of food” is considered to be a “best-buy” action that should be implemented as soon as possible to save lives by preventing diseases [75].

Besides the effects on blood pressure, a high salt intake may lead to the progression of renal disease, renal stones and stomach cancer and may be linked to the severity of asthma [63]. Recent studies additionally showed that a high salt intake among children and adolescents probably leads to a higher fluid consumption and in sugar-sweetened soft drink consumers to a higher consumption of soft drinks, which contributes to the risk of overweight [76; 77].

Despite these reports, the current average daily salt intake of most adult populations exceeds 6 g/day and in many, especially Asian countries, even 12 g/day. Also for children older than 5 years of age excessive salt intakes have been reported [78]. In Austria 47% of women, 60% of men, 72% of girls and 78% of boys (both aged 7 to 14 years) reportedly have salt intakes above 6 g/day [55].

In European and North American diets, most of the dietary sodium results from sodium chloride added to manufactured food (approximately 75% of intake in the U.S. and the UK) [79; 80]. The main contributors are cereals and cereal products (including bakery products, pasta, rice and breakfast cereals) as well as meat and meat products (including bacon, ham, sausages and meat dishes) [81-84]. Since the importance of convenience foods including fast foods, takeaways and ready meals is increasing steadily [5; 26; 49], the salt content of this product group has to be considered when assessing the daily salt intake.

In contrast to the problem with overweight, some countries have already made considerable progress with implementing effective national-wide salt reduction programmes. In Finland and the UK, for instance, the combination of food reformulation with improved food labelling and initiatives to raise consumer awareness has already successfully reduced the population salt intake [85-87].

1.2.3 Raised blood pressure

High blood pressure was the leading risk factor for global disease burden in 2010 with 7% of DALYs [58] and 9.4 million caused deaths [52]. A systolic and/or diastolic blood pressure equal or above 140/90 mmHg is defined as raised blood pressure. Estimates showed a global prevalence of about 22% in adults aged 18 years and above in 2014. That lowering blood pressure through individual and population-wide interventions is associated with health benefits was proven to be scientifically evident. There are many modifiable factors which contribute to the development of hypertension. Some of them are related to population diets, such as eating too salty, too many fat foods and an inadequate intake of fruits and vegetables [52]. Diets low in fruits and those high in sodium were shown to be the most important dietary risks related to global disease

burden. In total, dietary risk factors and physical inactivity together are responsible for 10% of global DALYs in 2010 [58]. Due to the positive health effects of a diet high in fruits and vegetables, the World Health Organisation recommends a minimum intake of 400 g of fruits and vegetables per day (excluding potatoes and other starchy tubers) [88]. The German Nutrition Society even suggests a daily intake of 400 g vegetables and 250 g fruits [89; 90]. To promote a higher fruit and vegetable consumption a global initiative was started by the World Health Organisation in 2003 [91] and various national public health campaigns (e.g. “Fruits & Veggies – More matters” in the U.S., “5 a day” in the UK, “5 am Tag” in Germany) were launched.

1.2.4 Guidelines for a healthy diet in comparison to the typical European dietary pattern

1.2.4.1 *Overview of nutrient based recommendations*

The dietary recommendations (RDIs) for energy, macronutrients and salt from various regions or countries are mostly in the same range [e.g. 66; 67; 69; 88; 92]. Long-term energy intake should balance energy expenditure to avoid overweight. In the last years convincing evidence was found that the total energy intake is more important than the macronutrient distribution expressed as energy percentages (%E) to maintain healthy body weight and optimal nutrient intakes [93].

Nonetheless, total fat intake should not be higher than 30%E for people with moderate physical activity. With high physical activity levels fat intake can be increased up to 35%E. The intake of saturated fatty acids (SFAs) should not exceed 10%E to keep cholesterol levels in normal range and to reduce the risk of coronary heart diseases (CHD) [94]. Thus, unsaturated fatty acids found in vegetable oils, nuts, avocados and fish are preferable to SFAs found in fatty meat, lard, palm oil, butter and high-fat milk products [95]. The intake of trans fatty acids (TFAs) should be limited to 1%E from all sources [96], since TFAs from partially hydrogenated fats have shown negative health effects on blood lipids, inflammatory response, endothelial function and CHD [97].

The carbohydrate intake should range from 50%E to 75%E. The nature of consumed carbohydrates seems to be a more important determinant for health outcomes than

the total carbohydrate intake. Hence, whole-grains, legumes, vegetables and fruits are the best sources for carbohydrates to protect against diabetes and CVDs [98]. To reduce the risk of overweight the consumption of sugar-sweetened beverages should be restricted and the intake of free sugars should be limited to less than 10%E [99].
As already mentioned above, the daily salt intake should not exceed 5 g [64; 66-69] or 6 g [65] to reduce the risk for hypertension.

1.2.4.2 *Recommendations for the overall composition of the diet*

For the prevention of major diet-related diseases a plant-based diet rich in any sort of vegetables, pulses, fruits, berries, whole grains, nuts, seeds, vegetables oils and vegetable oil-based fat spreads in combination with a high intake of low-fat dairy products and one or two portions fish per week is recommended [68; 100; 101]. This diet contains high amounts of dietary fibres, vitamins, minerals and other bioactive components (such as antioxidants, phenolic components and phytoestrogens) and delivers the types of carbohydrates and fat (including essential fatty acids from vegetables oils and the very long-chain n-3 fatty acids from oily fish) which are associated with health benefits. Thus, a plant-based diet reduces the risk for CVDs, hypertension, diabetes and some types of cancer and helps to prevent obesity [101].
Western-type dietary patterns, on the contrary, are linked to several adverse health effects and a higher risk for chronic diseases. For these diets a high intake of energy-dense food products with high amounts of added sugar and/or fat and a high salt content is typical. Further they are characterized by a high consumption of processed and red meats (e.g. beef, pork and lamb), which are associated with an increased risk for colorectal cancer, diabetes, obesity and CVDs. The associations for processed meats with the latter risks of disease were found to be strongly evident; the ones for red meats were weaker [101].

1.2.4.3 *Dietary changes needed to obtain health benefits*

Since there is a gap between dietary guidelines and population diets, some changes would be needed to obtain health benefits through diet. These are, based on foods, an

increased intake of vegetables, pulses, fruits, berries, nuts, seeds and fish, as well as a limited intake of processed and red meat, of beverages and foods with added sugars and of salt. Refined cereals should be exchanged to wholegrain cereals, butter to vegetable oils and high-fat dairy products to low-fat ones [100; 101].

1.3 Ready meals as part of populations diets

1.3.1 Associations between ready meal consumption and overweight

Several studies found that a higher intake of fast foods or meals outside home is likely to be associated with being overweight [for reviews see 102; 103]. Though, regarding ready meals, there are only few studies conducted so far. One study published from van der Horst et *al.* [23] also found a significant association between the ready meal consumption and overweight. They additionally found that overweight people have different beliefs about the nutritional value of ready meals compared to normal-weight respondents [23]. Another recently published study by Alkerwi et *al.* [104] described that a higher daily consumption of ready meals is significantly associated with abdominal obesity, measured by waist circumferences as indicator of central fat deposition. They also showed that ready meal consumption contributes to excess energy and fat intakes [104].

Hence, there are plausible hints that a higher consumption of ready meals increases the probability of weight gain and unhealthier diets; however, more research is definitely needed to confirm these assumptions.

1.3.2 The nutrient composition of ready meals

Only a few regional studies have been conducted regarding the nutrient composition of ready meals currently available Europe-wide [105-111]. The nutrient contents of German convenience foods have been estimated by recipe stimulation using nutrient content declared on the label and listed ingredients [105]. In the UK, a processed food database including on-pack levels of sodium, fat, sugar, and other nutrients from various processed foods, including some ready meals, has been established [106; 107].

The salt content of fast foods, takeaways, convenience foods, and ready meals has been examined more detailed. Particularly the salt contents of fast food and takeaway meals are alarmingly high [112-116]. The salt concentrations of convenience foods, including ready meals, soups or pizzas that are available on the Australian or British market showed high variations within meals of the respective food groups (e.g. pizzas) [84; 117-121]. The same was true for the salt content of fast foods, which varied not only by the type of food, but also by producer and country of origin [112].

To the best of my knowledge, no studies using laboratory methods to assess the macronutrients and salt of continental European convenience foods and ready meals have been conducted so far. Thus, one aim of the thesis, which was conducted as part of the EU-funded project "Double Fresh" (project No. FOOD-CT-2006-23182, www.doublefresh.eu), was to assess the overall nutritional quality of ready meals. To this end, ready meals from the Scandinavian region, the Benelux countries and Central Europe were analysed for their energy, protein, fat, fatty acids, carbohydrates, sugars and salt.

1.4 Implications for the future

Since in the upcoming years the consumption of fast foods, convenience foods and ready meals will increase, while otherwise cooking skills and the preparation of home-made meals will decrease, various strategies to enable consumers a balanced and healthy diet should be considered.

The implementation of public health initiatives to improve cooking skills from childhood to adultery with the aim to increase the self-efficacy related to meal management and meal preparation is one possibility [23-25]. This might have a positive effect on food choice, since better cooking skills are associated with a higher vegetable consumption [25]. A study from Caraher et *al.* [122] confirmed this association with a cooking intervention at school, which led to an increased children's vegetable consumption. At least due to higher cooking skills consumers are able to choose between home-made meals and pre-prepared meals [25].

Besides that, co-operations with the food industry enable several possibilities in promoting healthy diets. First, the food industry can ensure that there are healthy and nutritious choices available and affordable to all consumers [53]. To meet the ongoing convenience trend there is a need to develop healthy, affordable, child-acceptable convenience foods and ready meals [16; 19; 25]. This would allow working mothers under time pressures to feel good about the way they feed their families [19] and enable individuals to create quick and healthy meals [23]. Second, meal reformulation is a "key option to achieve population nutritional goals" [123]. Fat, sugar and salt concentrations of processed foods can be reduced by reformulated or new recipes [53]. Third, the practiced food marketing, especially the one aimed at children and teenagers, should be responsible [53]. Healthy foods should also be advertised and not only foods which are likely to be part of an unhealthy diet. For that reason, the World Health Organisation for Europe recently developed a nutrient profiling model. This model can be used to identify foods and beverages high in energy, saturated fats, trans fats, sugar or salt [124; 125] and should support governments with the implementation of marketing restrictions for "unhealthy" foods.

For optimising the nutritional composition of ready meals it has to be considered, that even the healthiest meals will only be accepted and purchased when consumers like it. The "liking" is influenced by flavour, appearance, texture, and odour and consumers are not willing to reduce their demand for tasty meals, not even for healthy ones [126].

As part of the thesis nutritional standards as proposed from Celnik et *al.* [14] were developed to evaluate the nutritional quality of the analysed ready meals. Hence, the published RDIs for adults from various European regions were used and, since the analysed ready meals were designed to replace one complete lunch or dinner without adding any further ingredients, 30% of the RDIs were set as benchmark for the nutritional evaluation.

Another aim of the thesis was to improve the nutritional quality of ready meals together with the producing companies through meal reformulation. To this end, some basic, easily understandable nutritional guidelines, specifically addressed to the food

industry, were established and published in different trade journals to reach as many companies as possible. Specific recommendations about the needs of children and overweight people were included. First attempts in developing healthier ready meals together with food industry partners were also part of the “Double Fresh” project. These newly developed ready meals were nutritionally evaluated using the same benchmarks as for the meals sold on the European market.

2 AIMS OF THE THESIS

The objective of the EU-funded project “Double Fresh” (project no. FOOD-CT-2006-23182, www.doublefresh.eu) was to assess and improve the overall quality of ready meals in terms of nutritional composition, sensory properties, food safety and packaging to extend the products´ shelf life. Therefore experts from different food science areas and nutrition worked together with small- and medium-sized enterprises. This thesis, as part of the study, was focused on the ready meals´ nutritional quality with the following aims:

- To analyse ready meals offered at the continental European market on their contents of energy, protein, fat, fatty acids, carbohydrates, sugars and salt in the laboratory.
- To identify nutritional imbalances by comparing the obtained results with benchmarks calculated from European RDIs for adults for one main meal.
- To evaluate comprehensively the labelled salt contents of convenience foods sold by Austrian retailers in order to include a higher number of meals.
- To investigate the differences between the obtained data and the nutrient contents labelled on the packages (in particular for macronutrients and energy).
- To establish some basic, easily understandable nutritional guidelines specifically addressed to the food industry, with the aim to improve the products´ nutritional value and to assist the food companies in developing new nutritionally optimised products.
- To disseminate the results not only in the scientific community, but also to the European food industry, especially ready meal-producers and retailers, through trade journals to enable future meal reformulations.
- To analyse the newly developed, supposedly nutritional optimised ready meals on the above mentioned parameters for evaluating the process of meal reformulation.

3 SAMPLES AND METHODS

3.1 Study design

A total of thirty-nine ready meals (32 plus 7) from seven European countries were analysed in the laboratory in two sampling rounds. In the beginning, thirty-two ready meals, currently offered to European consumers in supermarkets, were investigated. Then, seven meals were nutritionally optimised by meal reformulation in cooperation with the food company partners. Hence, we established basic, easily understandable nutritional guidelines. To evaluate the process of meal reformulation the newly developed meals were also analysed on the same parameters.

All meals were analysed for their total energy, composition of macronutrients, sugars, fatty acids and the salt concentration.

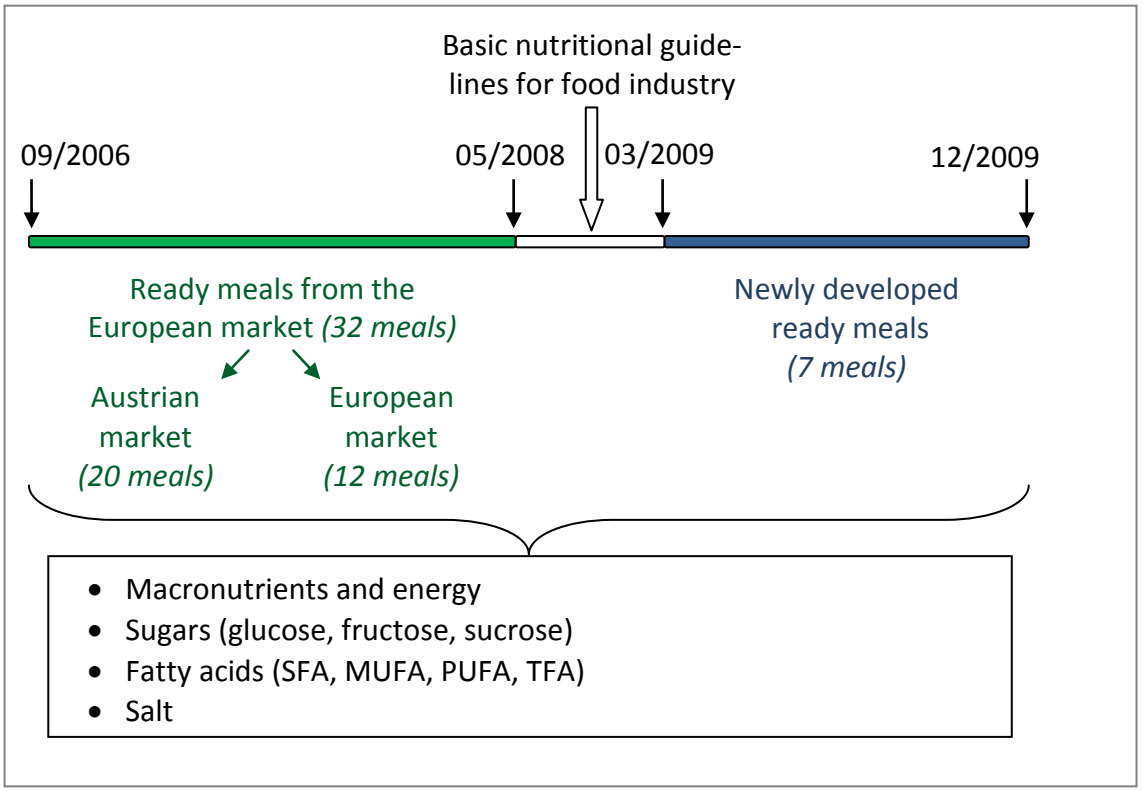

Figure 6. Overview of the samples and the analysed parameters

Additionally, a comprehensive survey of convenience foods offered at Austrian supermarkets was conducted in order to evaluate the salt contents of a wider range of products. Hence, in total the labels including the nutrient declaration of 572 convenience foods from the Austrian market were collected between April and July 2009.

3.2 Samples

3.2.1 Ready meals from the European market (*n* = 32)

A total of thirty-two ready meals offered to European consumers in supermarkets were investigated.

All meals met the above mentioned definition of home-meal replacements published by Costa et *al*. [33]. They comprised as main dish typically a fish or meat portion, a starchy component, such as rice/potatoes/noodles, a vegetable portion and/or a sauce, in single portion containers, designed to fully, and quickly, replace the main course of a home-made meal. No additional ingredients were necessary for preparation.

Most of the meals were packaged in a plastic tray, with one or more chambers for microwaveable heating, and were either chilled (25), frozen (5) or stored at room temperature (2).

The majority of the meals (31) were so-called ready-to-heat meals, which are prepared entirely by the food manufactures and the consumers have only to heat the meals prior to consumption. One meal included a raw salmon fillet as well as raw vegetables and, therefore, required additional microwave cooking before consumption (ready-to-cook meals).

In this study, no sweet dishes or calorie controlled meals were included.

Twelve ready meals were provided from food industry partners of the “Double Fresh” project. Of those ready meals five originated from the Scandinavian region (Finland and Norway), five from the Benelux countries (The Netherlands and Belgium) and another two from Central Europe (Switzerland). The twenty Austrian ready meals from

the most popular brands were sampled at retailers (leading markets as well as discount markets).

The main criteria for selection were sales figures (available through personal contact with food companies) and the food type. Frequently sold meals are often eaten and hence have a greater impact on consumers´ health than other meals. Since food choices differ throughout Europe, we included typical, commonly purchased, regional meals (provided by our industrial cooperation partners).
From our point of view, improvement of frequently consumed ready meals is of much higher relevance than providing healthier alternatives, which are purchased only scattered.

3.2.2 Newly developed ready meals (*n* = 7)

As already described the food industry partners developed seven supposedly nutritional optimised meals, which were also analysed. All of these meals were chilled and met the above-mentioned definition of home-meal replacements. Two meals were ready-to-cook meals with raw vegetables, a raw salmon fillet or a raw chicken breast; all the others were ready-to-heat meals.

Four meals were from the Scandinavian region (Finland and Norway); two from the Netherlands and one meal was from Germany.

3.2.3 Convenience foods from the Austrian market (*n* = 572)

For the comprehensive survey of convenience foods from the Austrian market, ready meals that met the above-mentioned criteria, but also main dishes without accompaniment, soups, hot sweet dishes (except desserts), cold sandwiches and salads were sampled one year after the laboratory analyses. All meals were ready-made and only had to be heated before consumption either without adding any further ingredients or with adding some water, milk and/or oil. Fourteen of the twenty laboratory-analysed meals were still available on the market, and thus included in the survey.

The collected ready meals were categorized into the following meal types: soups, pasta dishes, meat meals, pizzas, sweet meals, cold meals, salads, savoury dumplings, meals with potatoes/legumes/grains, fish meals and other meals. The definitions of each category including some examples can be found in Chapter 8 (supplemental Table S3).

3.3 Laboratory analyses

3.3.1 Sample preparation

Most of the ready meals were heated in a microwave oven, on the final day of shelf life, as specified on the label by the manufacturers including time and power. One meal was heated on an electric hob and the other in an electric oven.

After preparation the meals were weighed, immediately cooled on dry ice, homogenised and stored at -80 °C under nitrogen until further analyses (not longer than 4 weeks). For homogenising and lyophilising the meals a Mixer B-400 (Büchi, Flawil, Switzerland) and a freeze-dryer Lyolab B (Inula, Vienna, Austria) were used.

The edible portion of each meal was 100%. The sample size was always one pack, which in most cases was equivalent to one serving.

Two sub-samples per meal were taken from the Austrian meals (20) and five sub-samples from all the remaining European ready meals (19, 12 +7). These were taken from the same batch and analysed in duplicate. If the relative standard deviation (RSD) was larger than 3%, the analyses were repeated.

3.3.2 Macronutrients and energy

Total protein was determined by the Kjeldahl method [127]. The titration was done with a standardised hydrochloric acid (0.1 mol/l) until a pH-value of 6.10 was reached. To calculate protein from nitrogen, the factor 6.25 was used [128].

Total fat was extracted with an ASE® 100 system after hydrolysis with hydrochloric acid (25% w/w) using the modified method of Weibull-Stoldt [127; 129]. The amount of total fat was quantified gravimetrically.

Dry matter and ash were analysed gravimetrically as previously described by Matissek et *al*. [127]. The amount of total carbohydrates was obtained by subtracting the amounts of water, protein, total fat and ash from 100.

Energy content refers to the content of crude energy, derived by calculation from energy-yielding constitutes using energy conversion factors, i.e. 17, 37, and 17 kJ/g for protein, fat, and total carbohydrates, respectively [128].

3.3.3 Sugars glucose, fructose and sucrose

The sugars D-glucose, D-fructose and sucrose were determined by using a specific enzyme-linked colorimetric assay from Boehringer Mannheim/R-Biopharm (Darmstadt, Germany). It is based on an oxidative reaction of glucose, whereby the finally measured amount of nicotinamide adenine dinucleotide phosphate (NADPH) is stoichiometric to the amount of D-glucose in the sample. Fructose can be determined after the conversion to glucose by a phosphoglucose isomerase and sucrose after a hydrolysation step with β-fructosidase.

The used sample amount varied from 0.25 g to 1 g depending on the expected sugar content. At the beginning the fat of the homogenised and lyophilized samples was extracted with hot water and the obtained solution was clarified with Carrez reagents. The following photometric measurements at a wavelength of 340 nm and the calculations were done according to the instructions of the enzymatic test-kit.

3.3.4 Detailed fatty acid pattern

Fatty acids were determined by a gas chromatograph equipped with a flame ionisation detector (GC-FID) as previously published [129]. 0.4 g of the lyophilised sample was used for fat extraction. The GC-FID conditions for identifying and quantifying fatty acids are shown in Table 1.

Table 1. GC-FID conditions used for the quantification of fatty acids

GC-FID system	
Auto System Gas chromatograph with Flame Ionisation Detector (Perkin Elmer Inc., Vienna, Austria)	
Fused silica capillary column Rtx®-2330 (length 105 m, inside diameter 0.25 mm, film thickness 0.2 µm) (Restek Corp., Bellefonte, Pennsylvania, USA)	
TotalChrom Workstation, version 6.3.0 for peak integration (Perkin Elmer Inc., Vienna, Austria)	
GC-FID conditions	
Carrier gas	Helium
Injection volume	1 µl, split ratio 1:50
Temperature programme	100 °C for 10 min
	100 °C to 200 °C by 4 °C/min
	200 °C to 220 °C by 2 °C/min
	220 °C to 240 °C by 1 °C/min
	240 °C for 10 min
Detector temperature	275 °C

Identification of fatty acids was based on the samples´ retention times compared to known single or multiple standards (e.g. 37-Component FAME Mix standard from Supelco, Bellefonte, Pennsylvania, USA). The following fatty acids were considered: C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C20:0, C22:0, C24:0 as saturated fatty acids (SFAs), C16:1n7, C18:1n7, C18:1n9, C20:1n9, C22:1n9 as monounsaturated fatty acids (MUFAs), C18:2n6, C18:3n6, C18:3n3, C20:4n6, C20:5n3, C22:5n3, C22:6n3 as polyunsaturated fatty acids (PUFAs) and C16:1n9t, C18:1n7t, C18:1n9t, C18:1n12t, C18:2n6t, C20:1n11t, C22:1n13t as trans fatty acids (TFAs).
Based on the fatty acids in % of total fatty acids and the total fat content, fatty acids in g/100 g and in g/portion were calculated.

3.3.5 Salt by measuring the chloride content

The chloride or sodium present in the meals is added as salt during food processing. Consequently, the salt content can be calculated stoichiometrically from the ready meals´ chloride content, which was determined by a modified method of Mohr [(127)].

Therefore, approximately 0.5 g dried sample was heated with 20 ml added water to solve chloride. After cooling the chloride ions were determined by titrating with a standardised silver nitrate solution (0.1 mol/l) and 1 ml potassium chromate solution 5% (w/w) as indicator.

3.3.6 Quality assurance

The accuracy of the analyses was verified using the certified Standard Reference Material® 1846 (National Institute of Standards and Technology, Gaithersburg, USA). The recovery rates obtained were 99.1%, 98.5%, 99.4% and 105.1% for the analyses of protein, fat, dry matter and ash, respectively.

The methods reproducibility was verified by calculating RSD for a control sample (noodles with a zucchini-tomato sauce) ten times in one day and alongside the regular samples´ analyses. The mean values for protein, fat, dry matter and ash were 4.32 g, 1.68 g, 31.25 g and 1.28 g per 100 g control food sample. The RSDs from one day were 1.1%, 2.4%, 0.3% and 3.1% and between days 1.9%, 2.5%, 0.4% and 3.3% for the analyses of protein, fat, dry matter and ash, respectively.

To verify the accuracy of our method to analyse the detailed fatty pattern we participated at the 15th proficiency test 2009 from the German Society of Fat Science (DGF). In addition the same control food sample as for the macronutrients was run throughout the study to verify the methods´ reproducibility. The mean values for the main fatty acids were 8.37 %, 2.84 %, 22.28 %, 63.62 % and 0.81 % of total fatty acids for C16:0, C18:0, C18:1n9c, C18:2n6c and C18:3n3, respectively. The RSDs from one day were 1.51% for C16:0, 2.15% for C18:0, 0.70% for C18:1n9c, 0.46% for C18:2n6c and 6.75% for C18:3n3 and between days 4.32% for C16:0, 5.45% for C18:0, 0.97% for C18:1n9, 1.01% for C18:2n6 and 3.75% for C18:3n3.

For analysing the chloride content the method´s reproducibility was also verified by calculating RSD from measuring a control food sample (beef goulash with noodles).

The mean value for salt was 1.18 g/100 g. The RSD from one day was 1.67% and between days 1.59%.

3.4 Systemic survey of Austrian convenience foods

3.4.1 Data collection process

A total of 572 Austrian convenience foods from eight major food manufacturers (Knorr, Chef Menü, Iglo, Inzersdorfer, Wagner, Maggi, Spar Feine Küche and Dr. Oetker) and from one company providing organic products (Natur Compagnie) were included in the study. Data were collected at the supermarkets or from the companies´ web pages or by personal contact to the companies. In-store data were recorded either by manual transcription into a record book or by photography of the item. All data were entered into a bespoke spreadsheet. A random selection of records was verified against the original data source.

3.4.2 Product information collected

For each convenience food the brand name, product name, manufacturer, package size, number of portions per package, complete list of ingredients and the declaration of nutrients were collected. If only the sodium content was declared, salt was calculated by multiplying with 2.542.

3.5 Data presentation

All data were calculated per 100 g as well as per serving. The data obtained from the laboratory analyses were presented as means, minima (min) and maxima (max). From the collected data the number of products, the mean or median (depending on data distribution) and the range of salt contents were calculated in total, by meal category and by company.

3.5.1 Comparison with dietary reference intakes

Data obtained were compared with RDIs [66; 67; 69; 88; 92; 94; 98; 130] to evaluate the nutritional quality of the meals provided for the consumer. For the nutritional assessment, only the RDIs from the three European regions included in this study (Central Europe, Northern Europe, Benelux countries) and the ones from the EU regulation No. 1169/2011, were used. The recommendations are valid for the average intake over a longer period of time, e.g. at least over a week, since the dietary consumption may vary from meal to meal and from day to day. Given that a lunch or dinner should provide consumers with, on average, 30% of recommended amounts of energy and nutrients [14; 69; 131], the data obtained from analyses per serving were compared with 30% of RDIs for males and females between 30 and 50 years of age with a sedentary lifestyle. The RDIs used are presented in Table 2.

To evaluate the ready meals´ salt contents, the numbers of meals containing salt concentrations higher than the published targeted average salt intake level of 6 g/day [64; 66-69; 130] and the WHO recommendation of 5 g/day [65] for a main meal (= 30% of the RDIs) as well as for daily intake (100%) were calculated.

Table 2. Dietary recommendations for energy and macronutrients for males and females with sedentary lifestyle from three European regions calculated per serving (30% of RDIs)[a]

	Central Europe Deutsche Gesellschaft für Ernährung et al., 2013 [66]		**Northern Europe** Nordic Council of Ministers, 2004 [69]		**Benelux countries** Health Council of the Netherlands, 2001 [92]		**Regulation (EU) No. 1169/2011** [130]
Age	25-51 years		31-60 years		31-50 years		-
PAL	1.4		1.4		1.7		-
Energy, kJ	M: 3060 F: 2340		M: 3120 F: 2430		M: 3660 F: 2910		2520
Total Fat, g	<30%E	M: <25 F: <19	<30%E	M: <25 F: <20	<40%E[b]	M: <40 F: <31	<21
SFAs, g	<10%E	M: <8 F: <6	<10%E	M: <8 F: <7	<10%E	M: <10 F: <8	<6
MUFAs, g	13%E	M: 11 F: 8	10-15%E	M: 8-13 F: 7-10	8-38%E[c]	M: 8-38 F: 6-30	-
PUFAs, g	7%E	M: 6 F: 4	5-10%E	M: 4-8 F: 3-7			-
TFAs, g	<1%E	M: <0.8 F: <0.6	as low as possible		<1%E	M: <1.0 F: <0.8	-
Total CHO, g	>50%E	M: >90 F: >69	>55%E	M: >101 F: >79	-		>78
Sugars, g[d]	-		<10%E	M: <18 F: <14	-		<27
Protein, g	M: 18 F: 14		15%E	M: 28 F: 21	M: 18 F: 15		15

PAL = physical activity level, SFAs = saturated fatty acids, MUFAs = monounsaturated fatty acids, PUFAs = polyunsaturated fatty acids, TFAs = trans fatty acids, CHO = carbohydrates, %E = percentage of energy intake, M = male, F = female

[a] For calculating the amounts in g per serving from %E the energy conversion factors 37 kJ/g for fat, 17 kJ/g for total CHO and 17 kJ/g for protein were used.

[b] A fat intake up to 40%E is used for people with ideal body weight or ideal weight gain.

[c] Calculated on the basis of the dietary reference intakes for fat, SFA and TFA for a person with optimum weight.

[d] Refined sugars are defined as glucose, fructose, sucrose, starch hydrolysates and other isolated sugar preparations as such or added during food manufacturing.

3.5.2 Statistical analyses

To determine whether differences among the ready meals, depending on ingredients (food type), were significantly different, data were tested on normal distribution and then analysed by one-way analysis of variance (ANOVA) followed by Bonferroni post hoc test for homogenous or Dunnet-T3 for non-homogenous variances, or the Student´s *t* test.

The mean salt content of the ready meals originally available on the European market was compared with that from the newly developed ready meals (after meal reformulation) with a Student´s *t* test since all data were normally distributed.

To determine whether there were differences between the comprehensively surveyed, Austrian convenience foods depending on the meal type category and the producing company, the data (not normally distributed) were analysed by performing both the Kruskal-Wallis *H* test and the Mann-Whitney *U* test with Bonferroni adjustment for multiple testing.

Statistical differences were considered significant at $p<0.05$. All statistical analyses were performed using the statistical software package IBM SPSS version 20.0 for Microsoft Windows.

4 SUMMARY OF PUBLISHED RESULTS AND DISCUSSION

4.1 Composition of the ready meals

4.1.1 Ready meals currently available on the continental European market (*n* = 32)

Approximately 63% (*n* = 20) of the 32 ready meals contained meat (thereof 40% (8) white meat, 30% (6) pork and 30% (6) beef or venison). A further 16% (5) contained meat products such as sausage or bacon, and 16% (5) contained fish, which was salmon (Salmo salar), catfish (Pangasianodon hypophthalmus) or Pollack (Pollachius virens). The remaining 5% (2) were vegetarian meals. The starchy component in 41% (13) of the ready meals analysed was rice; 25% (8) contained potatoes, 22% (7) noodles and 16% (5) of the meals included dumplings, spaetzle (soft noodles made of wheat flour, eggs and salt) or similar. Nearly all the meals had a sauce (94%, 30) and half of them (53%, 17) different vegetables, legumes or fruits in an amount of more than 10% (w/w). The detailed ingredient lists according to the producers´ labels are presented in Chapter 8, supplemental Table S1.

4.1.2 Newly developed ready meals (*n* = 7)

One aim of the "Double Fresh" project was to create new, nutritionally balanced meals. From these seven newly developed meals, four contained meat (one chicken, two pork, one lamb), two meals fish (salmon) and one meal was designed for vegetarians. Side dishes were rice and noodles for two meals, and potatoes for three. All of the meals contained vegetables and a sauce. The lists of ingredients are available in supplemental Table S2 (Chapter 8).

4.2 Macronutrients and energy (Paper I)

Macronutrient content, water and energy of the analysed European ready meals are published in Paper I (see Appendix). Major results are summarised in this chapter.

4.2.1 Nutrient composition of the ready meals from the European market (*n* = 32)

4.2.1.1 *Differences between the meals according to the ingredients and the food type*

The assumption that ready meals with vegetables (*n*=17) have significantly more water (74.7 vs. 70.2 g/100 g; *p*=0.019) and significantly less energy (481 vs. 584 kJ/100 g; *p*=0.017) than those without vegetables (*n*=15) was confirmed. Importantly, this reinforces the fact that the addition of vegetables to a meal significantly reduces energy content.

Furthermore our results clearly imply that the composition of added sauces has a considerable impact on the meals´ total fat and, consequently, energy content. Hence, ready meal producers should be made more aware of the fact that adding vegetables and using sauces with less sugar, less oil or lard, and less high-fat milk-products (including cheese) can significantly improve the meals´ nutrient composition.

4.2.1.2 *Inter-package variation of nutrient composition and comparison of the analysed data with nutritional labelling given on the packages*

Large variations in the nutrient compositions between packages of the same batch were shown. This might be due to the filling process, which led to different amounts of meal components. For example, between the five different packages of salmon with potatoes which were considered for analyses, the sauce ranged from 67 g to 100 g. This led to a high variation of nutrients, particularly the fat content (19.04 ± 2.90 g/package).

Further, our data showed that in some cases the labelled nutrient content (e.g. for fat) exceeded the analysed values by 100%. Thus, besides accurate filling of the package, there is also a need for improved on-pack nutritional values to ensure trustworthy labels for consumers. Otherwise, the significance of mandatory nutrient labelling, as proposed in the EU regulation No. 1169/2011 [(130)], remains questionable. Manufacturers must implement all necessary measures to ensure reliable product labels.

4.2.1.3 *Nutritional evaluation*

Ready meals are usually designed to replace on main course. Therefore, macronutrients and energy per serving were compared to 30% of daily RDIs for males and females. In summary, the results of these evaluations indicate that the ready meals, on average, did not provide excess energy and fat. However, taking into account the low energy of the meals, the results clearly demonstrate that half of the meals were nutritionally imbalanced, providing elevated fat (>30%E) and low carbohydrate levels (<50%E).

4.2.2 Establishing easily understandable recommendations for the food producers to develop healthier meals

To address the problem of nutritionally unbalanced ready meals, we established simple and basic nutritional guidelines for the food industry. To reach as many companies and retailers as possible, these guidelines were published in various continental European trade journals, either in print or online (see Appendix). The guidelines are summarised in Table 3 (Chapter 4.4).

4.2.3 Nutrient composition of the newly developed ready meals (*n* = 7)

For developing the new ready meals it was important that the food industry partners considered the nutritional recommendations (Table 3, Chapter 4.4). Consequently, all newly developed meals contained a vegetable portion. Fat in five of the meals varied from 38%E to 42%E, which means only two meals met the recommended upper intake level of 30%E. Total carbohydrates in six of the meals were between 35%E and 45%E and, thus, still below the recommended lower intake level of 50%E.

As shown by these results, the implementation of guidelines was not totally effective when considering macronutrients. Reasons for this include only slightly changed recipes with small vegetable portions (30 g) and the addition of high amounts of sauce (up to 100 g). Only the pasta with spinach-ricotta filling had an optimal distribution of macronutrients. This meal was vegetarian since the pasta contained only a tomato sauce, fresh tomatoes, spinach leaves, cheese and pine nuts.

Two major limitations of the meal reformulation were observed. First, no nutritional experts were directly involved in the process of modifying the recipes in the various companies. Second, the focus of some ready meal producers was not only to optimise the nutritional value, but rather to "show" some improvements (e.g. by adding vegetables). Further, they were focused on extending the products´ shelf life and optimising their sensory quality. When dealing with nutritional optimisation, it must be kept in mind that even the healthiest meals are only accepted when specific sensory attributes are appreciated such as appearance, flavour, texture and odour [126].

4.3 Salt (Paper II)

The analysed salt concentrations of ready meals offered at European supermarkets and of the newly developed supposedly salt-reduced meals as well as the results of the comprehensive survey of Austrian convenience products overall and divided into the various meal type categories are published in Paper II (see Appendix).

4.3.1 Ready meals available on the continental European market (*n* = 32)

In total, the average salt content was 1.38 g/100 g. The salt contents of most meals ranged from 1 g/100 g to 2 g/100 g. Taking the portion sizes into account, all ready meals analysed exceeded 30% of the targeted average daily salt intake, which depending on the reference is either 1.8 g [64; 66-69] or 1.5 g [65]. More than 50% of the meals exceeded the more restrictive targeted daily intake level of 5 g [65] and almost 20% were above the more liberally set 6 g [64; 66-69].

A comparison to published data from Australian ready meals [117] showed that the average salt content analysed in the present study was higher, but the maximum levels were in the same range.

Back in 2003 ready meals with nearly 6 g salt per serving were also available on the British market [132]. However, four years later, after having implemented a nationalwide governmentally led salt reduction campaign that combined consumer education,

front-of-pack labelling and a voluntary food reformulation process [87], the average salt content of ready meals was successfully reduced [118; 133].

Thus, for ready meals in the UK combined governmental and food industrial efforts achieved a significant reduction of the meals´ average salt contents from 2003 to 2007 [118]. In contrast, average salt reduction in Australian ready meals failed [117]. The authors of the study identified as a major reason for the failure the lack of any coordinated salt reduction strategies from industry as a consequence of the missing governmental leadership. Additionally, the programme is voluntary and there is no systemic and objective monitoring [117].

The results of our study indicate that the salt contents of all analysed continental European ready meals are too high. Therefore, the next step within the European project was to develop new salt-reduced ready meals in cooperation with food-producing companies.

4.3.2 Nutrient composition of newly developed ready meals (*n* = 7)

In comparison to the previously available ready meals that had been analysed, the mean salt levels of the newly developed meals were significantly lower (0.90 g/100 g vs. 1.38 g/100 g; p=0.001), which refers to an effective implementation of meal reformulation guidelines. Since the sensory attributes of two newly developed ready meals were tested in a consumer panel and rated as very high (5.0 and 5.7, respectively, on a scale 1 = very dissatisfied and 7 = very satisfied) [126], our results show that a stepwise salt reduction through the process of meal reformulation is necessary and achievable without compromising the sensory quality and shelf life of the products.

4.3.3 Comprehensive survey of Austrian convenience foods (*n* = 572)

Nutrient declaration labels on 572 convenience foods from the Austrian market were collected. Sodium or salt contents were available for only 233 products (41% of all). The overall average level of all convenience foods was 1.07 g salt/100 g or 3.18 g salt/portion, whereby pizzas, pasta dishes and savoury dumplings had the highest salt

contents. Data from Australia and the UK collected from 2007 to 2009 report similar salt levels for pizzas [84; 119; 121] as were found within the present study.

Interestingly, large variations were found not only between the different meal type categories, but also within meal groups. Additionally, the salt contents of apparently similar ready meals produced by different companies were found to vary explicitly. The discussed variations found in the present study were also observed in other studies [117; 118].

Our results show that the salt contents of approximately 90% of all investigated Austrian convenience products exceeded 30% of the recommended targeted daily salt intake levels [64-69]. 21% of all meals had even higher salt concentrations than what is targeted by the WHO for one day (5 g) [65].

In summary, our results demonstrate that despite the above discussed large variations nearly all convenience products from the Austrian market are too high in salt.

4.3.4 Public health aspect

The feasibility and the public health impact of successfully implemented salt reduction programmes have been already demonstrated in the UK and in Finland [86; 87; 118; 134].

In Austria, however, there is no regulatory approach for reducing the salt content of convenience products in place. Moreover, a media campaign to raise consumer awareness regarding the negative impact of a high-salt diet on human health is missing and in 40% of the meals declaration of the sodium and/or salt content is not available. This makes it difficult for consumers to choose between low- and high-salt options.

The current issue of high salt concentrations in foods is comparable to the high levels of TFA in convenience products and fast foods some years ago. Comprehensive investigations on the TFA contents of various Austrian products confirmed that a harmful intake of TFAs was possible [129]. From there on, the government regulated the allowed amount of TFAs in foods by law [135]. This led to national-wide food reformulations by the food industry with the consequence that there are hardly any products with high TFA levels on the market any longer (unpublished results). Reduction policies for TFAs implemented in other countries or cities also resulted in lower TFA contents in the

food supply and hence, it can be concluded that "such policies are feasible, achievable and likely to have an effect on public health" [136].

Food reformulation in general is a "key option to achieve population nutrition goals" [123] and so far some examples such as the Finnish salt reduction initiative have shown positive effects on human health. A key part of this initiative is the mandatory salt labelling which led to the disappearance of many highly salted foods from the market and a greater variety of salt-reduced products [137]. Thereby, the public health initiatives in Finland led to a significantly lower salt intake that is reflected by a decrease in the 24 h urinary sodium excretion during the last 20 years [138]. Besides, a reduction in the average blood pressure by more than 10 mm Hg and a 75% to 80% decrease in mortality from both stroke and coronary heart disease could be observed [139]. These results are specifically important with regard to a different Finish cohort study, which showed that a 100 mmol higher 24 h urinary sodium excretion led to a 51% increased risk for CHD, a 45% increased risk for CVDs and a 26% increased all-cause mortality [140].

Asaria et *al.* [70] demonstrated that 8.5 million cardiovascular deaths in 23 countries could be averted by a 15% mean population salt intake reduction over a period of 10 years. The costs for implementing an adequate salt reduction programme were estimated to be US$ 0.09 per person per year.

4.4 Guidelines for the food industry (Trade journal publications)

As already mentioned above, we established nutritional guidelines for the food industry to address the problem of nutritionally unbalanced ready meals. To reach as many companies and retailers as possible, these guidelines were published in various continental European trade journals, either in print or online (see Appendix). The guidelines are summarised in Table 3.

The guidelines are in line with food-based recommendations for a healthy diet from various expert groups [68; 100; 101], such as the Nordic Nutrition Recommendations 2012

[101]. Though, our emphasis was to formulate them for the development of only one complete meal, namely a ready meal, and not for the whole diet. Since the major decision makers in the food industry are not nutrition experts, the guidelines were easy to understand.

Besides the dissemination through trade journals, the guidelines were also presented more detailed in a presentation for the food industry partners of the "Double Fresh" project. Recommendations for special groups, such as children, elderly and overweight people were included to inform the industry about their special needs for a healthy diet. A shortened version of the presentation was shown on a public workshop, which was organised within the "Double Fresh" project ("What can be said on the nutritional quality of chilled ready meals?"; see Project homepage www.doublefresh.eu).

Table 3. Guidelines for the food industry to improve the overall nutritional quality of ready meals (summarised)

1.	Appropriate energy content (<2500 kJ per serving of one main meal)
2.	Focus on carbohydrate rich starchy components such as potatoes, noodles and rice (preferring whole grain products if possible)
3.	Include different coloured vegetables, salads or fruits from different origin ("rainbow colours")
4.	Use of lean meat instead of the high fat parts and in a smaller amount than the side dishes
5.	Create some meals including sea fish or lake fish (also local fish)
6.	Not too much and not too fatty sauce
7.	Prefer plant oils such as corn oil, sunflower oil, walnut oil, rapeseed oil, olive oil or mixtures of these instead of animal fats
8.	Be cautious with the use of partially hydrogenated fats
9.	Use salt only in small amounts and improve taste with spices and/or fresh or dried herbs
10.	Especially for child-specific ready meals a low amount of salt is important to avoid that children´s taste adapts on salty

5 FURTHER UNPUBLISHED RESULTS AND DISCUSSION

5.1 Sugars glucose, fructose and sucrose

The results for glucose, fructose and sucrose in g/100 g from the continental European ready meals and from the newly developed ready meals are shown in Table 4 and Table 5.

5.1.1 Ready meals from the continental European market (*n* = 32)

On average the analysed ready meals contained 0.41 g glucose/100 g, 0.36 g fructose/100 g and 0.54 g sucrose/100 g.

5.1.1.1 *Glucose and fructose*

The highest contents of glucose and fructose (>0.8 g/100 g) were found in the following three meals: pasta with tomato-mozzarella sauce, pasta with sauce Bolognese and chicken with rice and curry sauce. This is explainable by the fact that, according to the ingredient lists (Table S1, Chapter 8), main components of the two pasta dishes were tomatoes and/or tomato puree (>25% of the entire dish). Tomatoes are natural sources of glucose and fructose. Cooked tomatoes, for instance contain 1.27 g glucose and 1.59 g fructose per 100 g edible portion and tomato puree 5.51 g glucose and 6.48 g fructose per 100 g [(141)]. High glucose and fructose concentrations were also found in other meals with added tomatoes and/or tomato puree, for example pasta with spicy tomato sauce or catfish with ratatouille and rice.

Another source for glucose and fructose were added fruits, fruit purees or fruit juices (mainly as concentrates). Examples are the chicken with rice and curry sauce and the venison ragout with dumplings. The chicken meal contained canned fruits (5.5%), banana puree (1.5%), pineapple (1.2%) and apple juices (0.6%) as concentrates, and tomato concentrate (0.8%). To the sauce of the venison ragout prunes were added (11% of the entire dish).

5.1.1.2 *Sucrose*

The pork in spicy tomato sauce with rice had by far the highest content of sucrose (4.82 g/100 g). In addition, higher contents of sucrose (>1 g/100 g) were found in the chicken with carrots, peas, potatoes; the chicken curry with rice and the chicken risotto. The high content of sucrose in the chicken with carrots, peas and potatoes is explainable by the included carrots (22% of the entire dish) and peas (14%). The main sugar in both vegetables is the naturally occurring sucrose [(141)], which is reflected by the meal´s high sucrose content.

The other meals with higher amounts of sucrose had the added sugar during food preparation in common. According to the ingredient list for the pork in spicy tomato sauce (Table S1, Chapter 8) the meal contained 27% sauce and sugar is the component with the second highest amount within the sauce (after water). An exact relative amount for sugar cannot be given since the recipe of the sauce was not available within the study. The same was observed for the chicken curry with rice and the chicken risotto. Thus, ready meal producers should be made aware of the fact that, besides the total fat content, also the added sugar has to be considered for creating an appropriate sauce for nutritionally balanced ready meals.

5.1.1.3 *Differences between the meals according to the food type*

No significant differences in sucrose were found between meat-based, fish-based and vegetarian meals. However, the vegetarian meals had significantly higher glucose concentrations (0.83 g/100 g) than the fish-based meals (0.29 g/100 g; p=0.030). The difference between vegetarian meals and meat-based meals was not significant (0.83 g/100 g vs. 0.40 g/100 g; p=0.054). Regarding the fructose content the differences found were also not significant (vegetarian meals 1.34 g/100 g vs. meat-based meals 0.30 g/100 g vs. fish-based meals 0.26 g/100 g). Thus, there is a tendency that vegetarian meals contain more glucose and fructose due to their higher amounts of vegetables, however the sample sizes are too small (vegetarian meals *n*=2; fish-based meals *n*=5).

5.1.1.4 *Nutritional evaluation*

The sum of glucose, fructose and sucrose per portion varied from 0.78 g to 29.84 g, with an average of 5.12 g/portion. Based on the meals´ energy the mean sugar content was 4.30%E. Since all analysed ready meals were designed to replace one complete main course, their nutritional values were assessed by comparing the obtained sugar contents with 30% of RDI (which is <10%E, see Table 2).

The only meal exceeding the RDI for sugars was the pork in spicy tomato sauce with rice. This meal contained 29.84 g glucose, fructose and sucrose/serving or 12.76%E. The main reason for this observation is the added sugar to the meal´s sauce.

Hence, the results of our study indicate that the contents of glucose, fructose and sucrose of nearly all ready meals are not too high (<10%E).

5.1.2 Newly developed ready meals (*n* = 7)

The sugar content of nearly all ready meals was appropriate and thus, the meal reformulation was not focused on their change. Consequently, there were no sugar-related guidelines established for the food industry. We emphasised to focus on whole-grain products, fruits, vegetables and legumes (see Table 3, Chapter 4.4), since these foods are recommended as the best sources for dietary carbohydrates [(98)].

The newly developed ready meals had mean concentrations of 0.48 g/100 g for glucose, 0.39 g/100 g for fructose and 0.34 g/100 g for sucrose.

The highest contents of glucose and fructose were found in pasta with spinach-ricotta filling, the only vegetarian meal, and the only one with added tomato puree and tomatoes (26% tomato sauce and 20% fresh tomatoes). Due to the included carrots the salmon with pasta and cauliflower (11% carrots) and the chicken with rice and vegetables (9% carrots) had the highest contents of sucrose.

Glucose, fructose and sucrose in total ranged from 3.06 g to 7.22 g/serving, with a mean of 5.14 g/portion or 3.92%E. In comparison with the RDI of <10%E the sugar concentrations of all meals were within the recommended range.

5.1.3 Public health aspect

The analyses within this study indicate that the ready meals´ sugar contents were below the RDI (that is <10%E) and consequently, no changes regarding these nutrients are necessary to develop nutritionally balanced ready meals. Though, it has to be considered that we excluded sweet dishes, which are as main dishes especially popular in Austria and their sugar contents are assumably higher.

The fact that, the sugar content of meals including fruits or vegetables such as tomatoes or carrots is higher should not encourage the development of meals without these ingredients to reduce their sugar contents. On the contrary, these foods besides whole-grain cereals are recognized as the best sources for dietary carbohydrates [98]. Since they are also important sources for micronutrients their higher intake is crucial and therefore promoted by the World Health Organisation and various national public health campaigns (e.g. “Five a day”) [91; 95].

Table 4. Glucose, fructose, sucrose and total sugars per 100 g edible portion of European ready meals (n = 32)[a]

Food names (number of sub-samples taken)	Glucose (g/100g)			Fructose (g/100g)			Sucrose (g/100g)			In total[b] (g/100g)		
	Mean	min	max	mean	min	max	mean	Min	max	mean	min	max
Chicken with rice and curry sauce (5)	0.85	0.81	0.90	0.96	0.92	1.01	0.59	0.52	0.65	2.39	2.32	2.49
Chicken risotto with mango sauce (5)	0.70	0.69	0.73	0.30	0.28	0.32	0.47	0.44	0.49	1.47	1.45	1.48
Chicken with carrots, peas, potatoes (5)	0.34	0.32	0.36	0.19	0.18	0.21	1.32	1.20	1.44	1.85	1.72	1.95
Chicken risotto (5)	0.64	0.59	0.68	0.48	0.45	0.51	1.11	1.02	1.17	2.23	2.06	2.34
Chicken curry with rice (2)	0.11	0.08	0.14	0.11	0.08	0.14	1.13	1.12	1.13	1.35	1.28	1.41
Asian rice dish with chicken (2)	0.37	0.36	0.37	0.21	0.20	0.22	0.77	0.74	0.79	1.34	1.30	1.38
Chinese chicken with rice (2)	0.46	0.43	0.49	0.30	0.28	0.31	0.78	0.76	0.80	1.54	1.51	1.56
Chicken with mushrooms and rice (2)	0.12	0.11	0.12	0.06	0.04	0.08	0.06	0.06	0.06	0.24	0.21	0.26
Brun lapskaus (5)	0.20	0.20	0.21	0.16	0.15	0.17	0.31	0.30	0.33	0.68	0.65	0.70
Pork in spicy tomato sauce with rice (5)	0.58	0.50	0.71	0.57	0.50	0.66	4.82	4.31	5.58	5.97	5.65	6.83
Roast pork with dumplings (2)	0.24	0.21	0.26	0.08	0.07	0.09	0.06	0.04	0.07	0.37	0.32	0.42
Minced meat with mashed potatoes (2)	0.45	0.45	0.45	0.14	0.14	0.14	0.24	0.23	0.25	0.83	0.82	0.84
Fillet of pork with rice (2)	0.19	0.18	0.19	0.16	0.15	0.17	0.36	0.35	0.37	0.71	0.68	0.73
Pork with cabbage and potatoes (2)	0.60	0.57	0.63	0.42	0.38	0.46	0.41	0.39	0.43	1.43	1.34	1.52
Kebab meat with rice and sauce (5)	0.28	0.25	0.31	0.16	0.15	0.19	0.25	0.23	0.27	0.70	0.67	0.73
Beef stroganoff with rice (5)	0.35	0.29	0.39	0.40	0.35	0.51	0.33	0.27	0.40	1.07	1.03	1.16
Beef goulash with spaetzle (2)	0.27	0.26	0.27	0.32	0.31	0.33	0.30	0.29	0.30	0.88	0.86	0.90
Pasta with sauce Bolognese (2)	0.89	0.85	0.93	0.89	0.85	0.92	0.36	0.33	0.38	2.13	2.03	2.23
Beef roulade with pasta (2)	0.33	0.31	0.34	0.27	0.26	0.28	0.27	0.26	0.27	0.86	0.84	0.88

Venison ragout with dumplings (2)	0.74	0.72	0.76	0.60	0.58	0.62	0.34	0.33	0.35	1.68	1.63	1.73
Aelpler Makkaronen (5)	0.18	0.15	0.20	0.08	0.04	0.13	0.29	0.19	0.40	0.54	0.43	0.68
Mashed potatoes, kale and sausage (5)	0.13	0.12	0.14	0.04	0.00	0.06	0.04	0.03	0.06	0.22	0.17	0.26
Lentil stew with dumplings (2)	0.15	0.14	0.15	0.09	0.08	0.09	0.11	0.11	0.11	0.34	0.34	0.34
Filled dumplings with sauerkraut (2)	0.32	0.31	0.33	0.09	0.09	0.09	0.16	0.15	0.16	0.57	0.56	0.57
Goulash with sausages and potatoes (2)	0.59	0.59	0.59	0.46	0.46	0.46	0.28	0.26	0.30	1.33	1.31	1.35
Salmon with potatoes and sauce (5)	0.17	0.16	0.20	0.11	0.10	0.12	0.31	0.29	0.32	0.59	0.55	0.64
Salmon with pasta and vegetables (5)	0.50	0.39	0.58	0.43	0.42	0.46	0.44	0.40	0.48	1.37	1.23	1.47
Salmon with pasta and spinach (2)	0.07	0.06	0.08	0.05	0.05	0.05	0.22	0.18	0.26	0.34	0.29	0.39
Catfish with ratatouille and rice (2)	0.57	0.54	0.59	0.58	0.55	0.61	0.19	0.17	0.21	1.34	1.30	1.37
Pollack with rice (2)	0.15	0.15	0.15	0.11	0.11	0.11	0.15	0.15	0.15	0.41	0.41	0.41
Pasta with spicy tomato sauce (2)	0.70	0.67	0.72	0.79	0.76	0.82	0.72	0.71	0.73	2.21	2.16	2.25
Pasta with tomato-mozzarella sauce (2)	0.97	0.96	0.98	1.89	1.88	1.89	0.11	0.11	0.11	2.97	2.95	2.98

[a] Results are presented as means, minima and maxima. From each sample (*n*) either two or five sub-samples were taken from the same batch. Where two sub-samples were taken the mean is equal to the median.

[b] Calculated by adding glucose, fructose and sucrose

Table 5. Glucose, fructose, sucrose and total sugars per 100 g edible portion of the newly developed ready meals (*n* = 7)[a]

Food names (number of sub-samples taken)	Glucose (g/100g)			Fructose (g/100g)			Sucrose (g/100g)			In total[b] (g/100g)		
	Mean	min	max	mean	min	max	mean	Min	max	mean	min	max
Chicken with rice and vegetables (5)	0.43	0.37	0.47	0.42	0.36	0.46	0.55	0.50	0.60	1.40	1.25	1.50
Pork with mashed potatoes, carrots (5)	0.49	0.47	0.52	0.21	0.20	0.22	0.39	0.37	0.42	1.09	1.06	1.13
Pork with mashed potatoes, broccoli (5)	0.48	0.47	0.51	0.22	0.21	0.23	0.15	0.13	0.16	0.85	0.83	0.90
Lamb with sauce, rice and vegetables (5)	0.50	0.42	0.55	0.47	0.39	0.55	0.18	0.14	0.21	1.15	0.95	1.31
Salmon with pasta and cauliflower (5)	0.36	0.35	0.37	0.34	0.33	0.36	0.62	0.54	0.67	1.32	1.27	1.37
Salmon with potatoes and broccoli (5)	0.28	0.23	0.34	0.27	0.22	0.31	0.27	0.24	0.29	0.82	0.74	0.92
Pasta with spinach-ricotta filling (5)	0.85	0.77	0.97	0.83	0.77	0.90	0.23	0.17	0.29	1.90	1.78	2.05

[a] Results are presented as means, minima and maxima. From each sample (*n*) five sub-samples were taken from the same batch.

[b] Calculated by adding glucose, fructose and sucrose.

5.2 Detailed fatty acid pattern

SFAs, MUFAs, PUFAs, TFAs, n-6 polyunsaturated fatty acids (n-6 PUFAs) and n-3 polyunsaturated fatty acids (n-3 PUFAs) in g/100 g from the continental European ready meals and from the newly developed ready meals are shown in Table 8 and Table 9.

5.2.1 Fatty acids from the currently available European ready meals (*n* = 32)

The mean contents of the analysed European ready meals were 1.71 g SFAs/100 g, 1.89 g MUFAs/100 g, 0.93 g PUFAs/100 g and 0.04 g TFAs/100 g. No statistically significant differences in the contents of SFAs, MUFAs, PUFAs and TFAs were found depending on the meal type or the ingredients used.

5.2.1.1 *Focus on SFAs*

Chicken risotto with mango sauce, salmon with pasta and spinach, minced meat with mashed potatoes, filled dumplings with sauerkraut and pasta with tomato-mozzarella sauce had the highest contents of SFAs (>3 g/100 g). Considering the lists of ingredients (Table S1, Chapter 8), two main reasons for the higher amounts of SFAs can be observed. These are firstly, the use of high-fat milk products such as cream or cheese, especially in the sauces (e.g. in the mango sauce or the cheese sauce), and secondly, the use of meat parts which are high in fat (e.g. for the minced meat or the filled dumplings). It has to be mentioned, that the salmon with pasta and spinach also included a high-fat cheese sauce and thus, was high in SFAs (4.1 g/100 g) and in total fat (9.5 g/100 g), as previously described in Paper I (see Appendix).

The lowest SFA (<0.3 g/100 g) and total fat (<1 g/100 g) contents of the meals analysed were found in the pasta with spicy tomato sauce, the chicken with carrots, peas and potatoes as well as the catfish with ratatouille and rice (see Paper I, Appendix).

Calculated per serving, SFAs in the ready meals analysed varied from 0.6 g to 17.5 g and taking energy into account, SFAs ranged from 1.4%E to 22.3%E, with an average of 11.3%E. More than the generally recommended 10%E of SFAs was found in 16 out of

32 ready meals. Thus, the fat quality of half of the meals was not recommendable and SFAs should be reduced.

5.2.1.2 *Focus on PUFAs, including the long-chain n-3 PUFAs eicosapentaenoic acid and docosahexaenoic acid*

The highest contents of PUFAs were found in the following four meals: Asian rice dish with chicken; beef goulash with spaetzle; beef roulade with pasta and roast pork with dumplings (>1.5 g/100 g). With reference to the list of ingredients (Table S1, Chapter 8), this can be explained by the use of vegetables oils. The type of oil exactly used was not given on the product´ labels. Since vegetable oils (e.g. soybean oil, corn oil, sesame oil, sunflower oil) are good sources for n-6 PUFAs [(94)], these meals also had the highest concentrations of n-6 PUFAs (>1.35 g/100 g).

The highest amounts of n-3 PUFAs were found in the three analysed meals with salmon: salmon with potatoes and sauce; salmon with pasta and vegetables as well as salmon with pasta and spinach (>0.4 g/100 g). Fatty fishes, such as salmon, sardines, tuna, herring and mackerel, are known to be good sources for the long-chain n-3 fatty acids eicosapentaenoic acid (EPA, 20:5n3) and docosahexaenoic acid (DHA, 22:6n3) [(94)]. As expected only the meals with salmon yielded significant amounts of EPA and DHA ranging from 0.11 g to 0.45 g/100 g or 0.38 g to 2.22 g/serving depending on the fish size (see Table 6).

Table 6. Eicosapentaenoic acid (EPA, C20:5n3) and docosahexaenoic acid (DHA, C22:6n3) in g per 100 g edible portion and per serving of European fish-based ready meals (n = 5)[a,b]

Food names (number of sub-samples taken)	EPA+DHA (g/100g)			Portion size[c] (g)	EPA+DHA (g/portion)
	Mean	min	max		Mean
Fish-based ready meals from the European market					
Salmon with potatoes and sauce (5)	0.45	0.36	0.55	490	2.22
Salmon with pasta and vegetables (5)	0.25	0.19	0.31	500	1.26
Salmon with pasta and spinach (2)	0.11	0.10	0.12	350	0.38
Catfish with ratatouille and rice (2)	0.02	0.01	0.02	350	0.06
Pollack with rice (2)	0.02	0.01	0.02	380	0.06

[a] Results are presented as means, minima and maxima. From each sample (n) either two or five sub-samples were taken from the same batch. Where two sup-samples were taken the mean is equal to the median.

[b] Calculated based on the fatty acids in % of total fatty acids and the total fat content.

[c] One serving is equivalent to the package size.

Brun lapskaus, a typical Norwegian meat stew and beef stroganoff with rice were the ready meals with the lowest contents of PUFAs (<0.2 g/100 g).

In total PUFAs ranged from 0.5 g to 7.7 g/serving or based on the meals´ energy from 0.9%E to 14.4%E, with a mean content of 6.4%E. In comparison with the RDIs (see Table 2), PUFAs in 20 out of 32 analysed ready meals were within the recommended range (5-10%E). The meals with the highest PUFAs concentrations in relation to total energy were the Asian rice dish with chicken (14.4%E), the beef roulade (12.0%E) and the beef goulash (11.5%E). As already mentioned above, this is explainable by the fact that for these meals vegetable oils were used.

Nine out of 32 meals provided only small amounts of PUFAs (<5%E). Their amount of PUFAs should be increased, for instance by using more plant oils instead of animal fats.

5.2.1.3 *Focus on TFAs*

To reduce the risk for CHD the recommended intake of TFAs from partially hydrogenated fats should be as low as possible. The highest TFA contents found in the analysed ready meals were 0.18 g/100 g, or 0.64 g/serving, or based on the meals´ energy content 0.89%E. The meals with the highest TFA contents were the kebab meat with rice and sauce, the salmon with pasta and spinach and the chicken risotto with mango sauce (>0.1 g/100 g). However, no analysed meal exceeded the recommended upper intake level, which is <1%E (see Table 2).

In Austria, the amount of TFAs in foods is regulated by law. Thus, only foods with maximal 2 g TFAs/100 g total fat are allowed to be offered at the market. For processed foods with more ingredients and a total fat content lower than 20% the allowed upper level for TFAs is 4 g /100 g total fat [(135)]. Within the analysed ready meals, no meal with a higher TFA content was found.

5.2.2 Fatty acids from the newly developed ready meals (*n* = 7)

On average the newly developed ready meals contained 1.95 g SFAs/100 g, 2.14 g MUFAs/100 g, 0.85 g PUFAs/100 g and 0.07 g TFAs/100 g. The highest amounts of SFAs were found in the two pork meals with mashed potatoes (>2.5 g/100 g). This is presumably caused by the use of high-fat parts from the pork. The pasta with spinach-ricotta filling had the lowest content of SFAs (<1.35 g/100 g). The two newly developed ready meals with salmon had, as expected, the highest concentrations of PUFAs (>1.45 g/100 g). EPA and DHA of these two meals are shown in Table 7.

Table 7. Eicosapentaenoic acid (EPA, C20:5n3) and docosahexaenoic acid (DHA, C22:6n3) in g per 100 g edible portion and per serving of the newly developed fish-based ready meals (n = 2)[a,b]

Food names (number of sub-samples taken)	EPA+DHA (g/100g)			Portion size[c] (g)	EPA+DHA (g/portion)
	mean	min	max		mean
Newly developed fish-based ready meals					
Salmon with pasta and cauliflower (5)	0.32	0.28	0.35	470	1.47
Salmon with potatoes and broccoli (5)	0.31	0.27	0.37	440	1.38

[a] Results are presented as means, minima and maxima. From each sample (n) five sub-samples were taken from the same batch.

[b] Calculated based on the fatty acids in % of total fatty acids and the total fat content.

[c] One serving is equivalent to the package size.

Calculated per serving the newly developed ready meals contained 5.0 g to 10.2 g SFAs and 1.6 g to 6.8 g PUFAs. Taking the meals´ energy content into account, SFAs ranged from 8.9%E to 18.6%E and PUFAs from 2.8%E to 11.3%E. Compared with the RDIs nearly all meals provided elevated levels of SFAs (>10%E). Only the pasta with spinach-ricotta filling had a lower SFA content (8.9%E). More than half of the meals provided less PUFAs than recommended (<5%E). The two salmon meals were the only ones with higher PUFA concentrations (8.7%E and 11.3%E).

Regarding the fatty acid pattern no differences were found between the European ready meals and the newly developed ready meals. Hence, the food reformulation to improve the fat quality of the ready meals was not effective. The limitations of our reformulation are discussed in Paper I (see Appendix).

5.2.3 Public health aspect

The results from this study demonstrate that SFAs in 50% of the analysed European ready meals were too high (>10%E) and PUFAs in approximately 28% of the meals too low (<5%E).

Higher amounts of SFAs were caused by the use of high-fat milk products such as cream or cheese, for instance for the sauces, and by the use of meat parts which are high in fat. The ready meals with vegetable oils were richer in PUFAs. The results further confirm that ready meals with salmon had high amounts of the long-chain n-3 PUFAs EPA and DHA.

Hence, a better fat quality can be achieved by changing fatty meats, lard, butter, cheese and other high-fat milk products, such as cream with lean cuts of meats, vegetable oils (except palm oil and coconut oil) and low-fat milk-products. Additionally, food industry should be encouraged to develop more ready meals with fatty fish (e.g. salmon, herring, tuna, mackerel), since they are a good source for the long-chain fatty acids EPA and DHA [(94)].

The results have shown that the fat quality of the newly developed meals is still not recommendable. Thus, further effort is needed to inform the food industry about the need and the possibilities to improve the fatty acid pattern.

Table 8. SFAs, MUFAs, PUFAs, TFAs, n-6 PUFAs and n-3 PUFAs per 100 g edible portion of European ready meals (n = 32)[a,b]

Food names (number of sub-samples taken)	SFAs[c] (g/100g)			MUFAs[d] (g/100g)			PUFAs[e] (g/100g)			TFAs[f] (g/100g)	n-6 PUFAs[g] (g/100g)	n-3 PUFAs[h] (g/100g)
	mean	Min	Max	mean	min	Max	mean	min	max	mean	mean	mean
Chicken with rice and curry sauce (5)	0.86	0.80	0.94	0.75	0.71	0.80	0.80	0.75	0.84	0.03	0.79	0.02
Chicken risotto with mango sauce (5)	4.28	3.65	4.82	3.28	2.75	3.74	0.64	0.54	0.72	0.13	0.63	0.02
Chicken with carrots, peas, potatoes (5)	0.22	0.19	0.23	0.38	0.32	0.41	0.30	0.28	0.32	0.02	0.25	0.05
Chicken risotto (5)	0.42	0.39	0.46	0.80	0.75	0.86	0.76	0.71	0.83	0.01	0.71	0.05
Chicken curry with rice (2)	2.30	2.13	2.47	0.33	0.27	0.38	0.29	0.22	0.35	0.01	0.27	0.02
Asian rice dish with chicken (2)	0.61	0.58	0.64	1.08	1.05	1.10	2.22	2.18	2.25	0.02	2.01	0.20
Chinese chicken with rice (2)	0.59	0.57	0.61	0.77	0.72	0.81	0.61	0.57	0.65	0.00	0.57	0.04
Chicken with mushrooms and rice (2)	1.80	1.72	1.88	1.09	1.06	1.11	0.80	0.78	0.82	0.03	0.76	0.05
Brun lapskaus (5)	0.57	0.50	0.77	0.60	0.53	0.69	0.18	0.16	0.20	0.01	0.16	0.02
Pork in spicy tomato sauce with rice (5)	1.05	0.97	1.23	3.48	2.94	3.78	1.35	1.15	1.45	0.03	1.04	0.31
Roast pork with dumplings (2)	2.87	2.63	3.11	4.53	4.22	4.84	1.53	1.19	1.87	0.03	1.36	0.18
Minced meat with mashed potatoes (2)	3.65	3.60	3.69	4.42	4.37	4.47	1.41	1.39	1.43	0.06	1.31	0.10
Fillet of pork with rice (2)	2.48	2.34	2.62	1.79	1.57	2.01	1.22	1.17	1.26	0.10	1.17	0.05
Pork with cabbage and potatoes (2)	1.78	1.75	1.80	1.92	1.89	1.95	0.57	0.49	0.64	0.03	0.53	0.04
Kebab meat with rice and sauce (5)	2.58	2.38	2.84	3.29	3.15	3.53	0.42	0.39	0.43	0.16	0.41	0.01
Beef stroganoff with rice (5)	0.76	0.64	0.86	0.50	0.38	0.58	0.11	0.10	0.11	0.03	0.08	0.02
Beef goulash with spaetzle (2)	0.80	0.75	0.84	1.29	1.23	1.34	1.75	1.72	1.78	0.01	1.72	0.04
Pasta with sauce Bolognese (2)	1.97	1.89	2.05	2.09	2.01	2.16	0.89	0.89	0.89	0.09	0.86	0.04
Beef roulade with pasta (2)	1.03	1.01	1.04	1.73	1.71	1.75	1.55	1.48	1.61	0.03	1.48	0.07

Venison ragout with dumplings (2)	0.93	0.88	0.98	1.02	1.01	1.03	1.14	1.11	1.17	0.03	1.06	0.09
Aelpler Makkaronen (5)	2.10	2.07	2.18	1.89	1.85	1.99	1.07	1.05	1.10	0.08	1.02	0.04
Mashed potatoes, kale and sausage (5)	2.13	1.97	2.33	2.67	2.55	2.74	1.21	0.97	1.37	0.03	1.10	0.12
Lentil stew with dumplings (2)	1.51	1.44	1.57	2.29	2.18	2.40	1.15	1.12	1.17	0.01	1.06	0.09
Filled dumplings with sauerkraut (2)	3.31	3.11	3.50	3.83	3.61	4.04	1.07	1.01	1.13	0.04	1.01	0.07
Goulash with sausages and potatoes (2)	2.94	2.89	2.98	3.40	3.40	3.40	1.02	1.00	1.03	0.04	0.95	0.07
Salmon with potatoes and sauce (5)	1.20	1.07	1.37	1.50	1.17	1.99	1.14	0.92	1.41	0.05	0.48	0.65
Salmon with pasta and vegetables (5)	0.97	0.85	1.08	1.96	1.78	2.18	1.13	1.02	1.28	0.03	0.66	0.47
Salmon with pasta and spinach (2)	4.13	4.07	4.18	3.78	3.74	3.82	1.39	1.36	1.42	0.18	0.93	0.46
Catfish with ratatouille and rice (2)	0.25	0.23	0.27	0.27	0.25	0.29	0.23	0.19	0.26	0.00	0.19	0.03
Pollack with rice (2)	1.42	1.35	1.48	0.98	0.93	1.03	0.94	0.84	1.04	0.02	0.91	0.03
Pasta with spicy tomato sauce (2)	0.18	0.16	0.20	0.27	0.22	0.31	0.30	0.26	0.34	0.00	0.28	0.02
Pasta with tomato-mozzarella sauce (2)	3.05	2.88	3.21	2.43	2.43	2.43	0.47	0.46	0.47	0.09	0.41	0.06

SFAs = saturated fatty acids, MUFAs = monounsaturated fatty acids, PUFAs = polyunsaturated fatty acids, TFAs = trans fatty acids, n-6 PUFAs = n-6 polyunsaturated fatty acids, n-3 PUFAs = n-3 polyunsaturated fatty acids

[a] Results are presented as means, minima and maxima. From each sample (*n*) either two or five sub-samples were taken from the same batch. Where two sub-samples were taken the mean is equal to the median.

[b] Calculated based on the fatty acids in % of total fatty acids and the total fat content.

[c] SFAs include C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C20:0, C22:0 and C24:0.

[d] MUFAs include C16:1n7, C18:1n7, C18:1n9, C20:1n9 and C22:1n9.

[e] PUFAs include C18:2n6, C18:3n6, C18:3n3, C20:4n6, C20:5n3, C22:5n3 and C22:6n3.

[f] TFAs include C16:1n9t, C18:1n7t, C18:1n9t, C18:1n12t, C18:2n6t, C20:1n11t and C22:1n13t.

[g] n-6 PUFAs include C18:2n6, C18:3n6 and C20:4n6.

[h] n-3 PUFAs include C18:3n3, C20:5n3, C22:5n3 and C22:6n3.

Table 9. SFAs, MUFAs, PUFAs, TFAs, n-6 PUFAs and n-3 PUFAs per 100 g edible portion of the newly developed ready meals (*n* = 7)[a,b]

Food names (number of sub-samples taken)	SFAs[c] (g/100g)			MUFAs[d] (g/100g)			PUFAs[e] (g/100g)			TFAs[f] (g/100g)	n-6 PUFAs[g] (g/100g)	n-3 PUFAs[h] (g/100g)
	mean	min	Max	mean	min	Max	mean	min	max	mean	mean	mean
Chicken with rice and vegetables (5)	1.38	1.32	1.43	1.04	0.96	1.15	0.44	0.38	0.50	0.05	0.31	0.14
Pork with mashed potatoes, carrots (5)	2.58	2.37	2.91	2.16	1.75	2.41	0.67	0.52	0.84	0.11	0.51	0.16
Pork with mashed potatoes, broccoli (5)	2.65	2.53	2.77	2.54	2.36	2.74	0.79	0.70	0.89	0.06	0.58	0.21
Lamb with sauce, rice and vegetables (5)	2.11	1.98	2.27	3.11	2.85	3.91	0.67	0.60	0.72	0.12	0.61	0.07
Salmon with pasta and cauliflower (5)	2.17	2.07	2.28	2.91	2.80	3.06	1.46	1.33	1.57	0.06	0.81	0.65
Salmon with potatoes and broccoli (5)	1.44	1.36	1.50	2.18	1.95	2.37	1.51	1.39	1.68	0.04	0.93	0.58
Pasta with spinach-ricotta filling (5)	1.32	1.21	1.51	1.08	1.03	1.21	0.41	0.37	0.43	0.04	0.34	0.07

SFAs = saturated fatty acids, MUFAs = monounsaturated fatty acids, PUFAs = polyunsaturated fatty acids, TFAs = trans fatty acids, n-6 PUFAs = n-6 polyunsaturated fatty acids, n-3 PUFAs = n-3 polyunsaturated fatty acids

[a] Results are presented as means, minima and maxima. From each sample (*n*) five sub-samples were taken from the same batch.

[b] Calculated based on the fatty acids in % of total fatty acids and the total fat content.

[c] SFAs include C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C20:0, C22:0 and C24:0.

[d] MUFAs include C16:1n7, C18:1n7, C18:1n9, C20:1n9 and C22:1n9.

[e] PUFAs include C18:2n6, C18:3n6, C18:3n3, C20:4n6, C20:5n3, C22:5n3 and C22:6n3.

[f] TFAs include C16:1n9t, C18:1n7t, C18:1n9t, C18:1n12t, C18:2n6t, C20:1n11t and C22:1n13t.

[g] n-6 PUFAs include C18:2n6, C18:3n6 and C20:4n6.

[h] n-3 PUFAs include C18:3n3, C20:5n3, C22:5n3 and C22:6n3.

6 MAIN FINDINGS AND CONCLUSION

Although ready meals play an important role in today's food consumption patterns, only few studies on their nutritional quality were conducted until now. To the best of my knowledge, this was one of the first studies, in which the nutrient composition of continental European ready meals was laboratory analysed.

The results of the present investigation indicate that half of the analysed continental European ready meals were nutritionally imbalanced with too high fat (>30%E) and too low carbohydrate levels (<50%E). Regarding fatty acids, 50% of the ready meals delivered more SFAs and 28% less PUFAs than recommended (for SFAs >10%E, for PUFAs <5%E). Thus, the fat quality of half of the ready meals should be improved. Additionally, the data prove that the salt concentrations of the analysed ready meals and of the comprehensively surveyed Austrian convenience foods mostly exceed the targeted intake level for one meal (30% of RDIs) and some even the daily recommended dose of 6 g (100%).

Large variations of the labelled salt levels from the Austrian convenience foods (in total from 0.23 to 7.37 g/100 g) were found not only between and within the different meal type categories, but also between similar meals from different companies. In one case, a pasta dish contained 149% more salt than the same meal from a competitive producer.

Furthermore, the results identified inaccuracies with packages filling and with on-pack nutrient labelling. Hence, mandatory nutritional labelling as proposed in the EU regulation No. 1169/2011, will only be useful for consumers, if additional food quality measurements are implemented by food manufacturers, and checked by food safety authorities.

The study highlights that through some modifications within the recipes the ready meals´ nutritional quality can be improved considerably. These changes are the addition of vegetables and the use of sauces with less added sugar, lard, butter, cheese or other high-fat milk products such as cream. The fact that the use of lean cuts of meat, low-fat milk products and vegetable oils (except palm oil and coconut oil) results in a

better fat quality was also confirmed. Since the salmon-based ready meals were found to be good sources for essential and non-essential PUFAs, especially for the long-chain n-3 PUFAs EPA and DHA, the food industry should be encouraged to create more ready meals with fatty fish.

First steps in improving the nutritional quality of ready meals have been set within this study, for instance with the published guidelines for the food industry. The nutrient composition of one newly developed meal was according to the recommendations. The meal – a vegetarian pasta dish with spinach-ricotta filling, a tomato sauce, mozzarella pearls, hard cheese and pine nuts – had an optimal distribution of macronutrients, a high content of naturally occurring sugars due to the included vegetables and a low content of SFAs.

Since salt in the newly developed ready meals was significantly lower, the data of this study support the fact that a stepwise reduction of the ready meals´ salt concentration by meal reformulation is feasible without compromising the sensory quality and the products´ shelf life.

The importance of ready meals is likely to persist and thus different ways of addressing the problem of nutritionally unbalanced meals should be discussed. Creating and offering consumers a wider range of affordable ready meals with appropriate energy content, balanced macronutrient distribution, a high fat quality, low salt levels and a desirable sensory quality, would give the consumers at least a choice to choose between the traditional meals and the “healthier” ones.

Besides that, the food industry should be encouraged for responsible food marketing strategies and public health initiatives to lower the population intake of critical nutrients, such as salt or SFA should be considered. Regarding salt concentrations in foods there are already governmental-led strategies successfully established in the UK or Finland. Until today, it seems that legislation with either governmentally set salt reduction targets for various food groups or with mandatory labelling of salt contents is more efficient than a voluntary-based programme without any monitoring.

Either way, in the coming years further efforts are needed to enable consumers the preparation of a quick, tasty and healthy meal for themselves and their families. Even

if they would chose the healthier options only sometimes, this would have an impact on their health.

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8 SUPPLEMENTAL MATERIAL

Table S1. Ingredients of European ready meals according to the product labels

Food names	Ingredients according to the product labels
Chicken with rice and curry sauce	Rice, chicken breast, curry sauce (cream, canned fruits (peach, pear, cherry, grape, pineapples, sugar, water), banana puree, pineapple juice (concentrate), dry milk powder, tomato puree, vegetable oil, apple juice (concentrate), modified starch, aroma, spices e.g. curry powder, salt, coconut milk powder, sugar, thickener), almonds roasted
Chicken risotto with mango sauce	Water, rice, chicken (chicken, water, salt, stabilizer, vegetable oil, spices, yeast extract, dextrose, sodium glutamate, ascorbic acid), chicken meat product (chicken, water, sodium lactate, potassium lactate, salt, modified starch, potato fibre, glucose, spices, hydrolysed vegetable protein, pyrophosphate, sodium triphosphate, ascorbic acid, preservative, modified starch), sauce (crème fraiche, water, rapeseed oil, sugar, vinegar, modified starch, salt, tomato, onion, milk protein, jalapeno, mango, lemon juice, mustard seeds, garlic, chili, starch, spices (e.g. coriander, turmeric, pepper), sodium glutamate, preservative, colorant, aroma), bell pepper, chives
Chicken with carrots, peas, potatoes	Carrots and peas (carrots, peas, vegetable oil, salt, soya protein, sodium glutamate, flavours, spices, yeast extract), potatoes (potatoes, vegetable oil, salt, dispersant, flavour, colorant), chicken breast in flesh gravy (chicken, water, pepper, dried onion, garlic, wheat flour, herbs, spices, sodium glutamate, stabilizer, salt, soya protein, vegetable oil, preservative, sugar, citric acid, dextrose, starch, antioxidant, flavour, colorant, wheat protein, malt dextrin, thickener, yeast extract)

Chicken risotto	Rice, chicken (chicken, salt, milk protein, starch, sugar, dextrose, stabilizer, aroma), leek, cabbage, bell pepper, green bean, sauce (peanuts, sugar, water, vinegar, soya sauce, aroma, curry, modified starch, salt, sambal ulek, vegetable oil, milk protein, Worcester sauce, stabilizer, brown syrup, preservative, flavour enhancer), sweet soya sauce (glucose syrup, water, salt, sugar, soya protein, colorant), water, salt, onion, oil, tomato ketchup (tomatoes, glucose syrup, vinegar, modified starch, salt, acidifier, thickener, preservative), modified starch, sambal ulek, paprika, sugar, vegetable bouillon, aroma salt (salt, starch, dextrose, herbs, curry), onion, garlic, white pepper
Chicken curry with rice	Rice, curry sauce (water, coconut milk, skimmed milk, sugar, wheat flour, curry powder, spices, sodium acetate, citric acid, ascorbic acid, modified starch, salt, chicken bouillon), chicken breast, pineapples, red bell pepper
Asian rice dish with chicken	Rice with vegetables (rice, carrots, onion, peas, cabbage, bell pepper, bean sprouts, mushrooms, sauce (water, soy, wheat, salt, malt dextrin, onion, yeast, vegetable oil, spices, sugar), vegetable oil, aroma, vinegar, salt, spices e.g. chili powder), chicken (chicken, salt, dextrose, starch, vegetable oil, spices, ascorbic acid)
Chinese chicken with rice	Vegetables (green beans, champignon, carrots, broccoli, soya bean sprouts), rice, sauce (water, soya sauce (water, soya beans, salt), chili sauce (water, sugar, chili, garlic, salt), rice vinegar, sugar, sesame, sesame oil, garlic, ginger, chicken bouillon, thickener, sodium acetate, citric acid, ascorbic acid), chicken breast
Chicken with mushrooms and rice	Chicken breast with mushroom sauce (water, chicken breast, champignon, cream, onion, wheat flour, vegetable oil, beef bouillon, modified starch, milk powder, salt, aroma, parsley, pepper), rice (water, rice, sunflower oil, salt)
Brun lapskaus	Potatoes, water, pork, beef, carrots, leek, Swedish turnip, celeriac, onions, potatoes flakes, starch, meat bouillon, salt, colorant, white pepper

Pork in spicy tomato sauce with rice	Pork with tomato sauce (Water, pork, lard, sugar, white cabbage, tomato puree, carrots, onion, modified starch, vinegar, vegetable oil, ginger puree, salt, garlic puree, sambal, yeast extract, curcuma, sweetener), rice (water, rice, pork, leek, egg, vegetable oil, herbs, spices, sodium glutamate, thickener, antioxidant, preservative, stabilizer, aroma, citric acid)
Roast pork with dumplings	Dumplings (buns (wheat flour, yeast, salt, lecithin), water, milk, egg, vegetable oil, wheat flour, onion, starch, salt, parsley, spices), pork (pork, water, salt, spices, polyphosphate, sodium glutamate), sauce (water, gravy, modified starch, beef bouillon, vegetable oil, salt, onion, garlic, spices)
Minced meat with mashed potatoes	Mashed potatoes (water, mashed potato powder, milk powder, vegetable oil, salt, thickener, colorant), minced meat (pork, onion, buns (wheat flour, water, yeast), spices (paprika, marjoram, pepper), aroma, salt, egg, garlic, parsley, vegetable oil), sauce (water, onion, gravy, wheat flour, modified starch, aroma, beef bouillon)
Fillet of pork with rice	Pork fillet with sauce (pork, water, milk, stock (beef bouillon, water, tomato puree, carrots, onion, celery, salt, parsley, wheat flour, spices), cream, onion, butter, wheat flour, beef bouillon, starch, parsley, herbs), rice with peas (rice, water, peas, sunflower oil, salt, starch, sugar, yeast, onion, celery, garlic, spices)
Pork with cabbage and potatoes	Cabbage (water, sauerkraut, onion, sour cream, tomato puree, garlic, vegetable bouillon, spices, wheat flour, salt, sugar, sodium acetate, citric acid, ascorbic acid, caraway, modified starch, pork bouillon), pork (pork, salt, spices, vegetable oil), potatoes (potatoes, salt)
Kebab meat with rice and sauce	Rice (water, rice, salt, sodium glutamate, sugar, aroma, spices), kebab meat (minced beef, water, fibre, salt, spices, sodium glutamate, glucose), sauce (crème fraiche, tomato, salt, vegetable oil, orange juice, onion, jalapeno, vinegar, sugar, modified starch, milk protein, lemon juice, mustard seeds, spices (e.g. turmeric, pepper), sodium glutamate, hydrolysed vegetable protein, thickener, citric acid, preservative, acidic acid, colorant, aroma), chili pepper, bell pepper, salt

Beef stroganoff with rice	Rice, beef, sauce (water, pepper, onion, champignon, chopped tomato, tomato puree, crème fraiche, maize starch, flour, salt, sugar, malt dextrin, yeast, rot celery powder, onion, lactose, spices)
Beef goulash with spaetzle	Sauce (water, onion, vegetable oil, spices, wheat flour, salt, modified starch, vinegar), spaetzle (water, durum wheat flour, egg, vegetable oil, salt, spices), beef
Pasta with sauce Bolognese	Sauce (water, tomato puree, beef, vegetables (carrots, celery, onion), vegetable oil, concentrate of tomatoes, red wine, modified starch, salt, yeast extract, onion, wheat flour, vegetable oil, malt dextrin, sugar, starch, celery, spices, herbs, aroma), pasta (durum wheat flour, water, salt, vegetable oil)
Beef roulade with pasta	Pasta (durum wheat flour, egg white, sunflower oil), beef roulade (beef, pork, pickled gherkin, carrots, water, rice, bacon, salt, spices, celery, yellow carrots, sunflower oil, onion, wheat flour, modified starch, milk powder, mustard, red currant jam, red wine, vinegar, stabilizer, sodium glutamate, ascorbic acid, colorant)
Venison ragout with dumplings	Red wine sauce with plums (water, red wine, prune, onion, celery, wheat flour, modified starch, rapeseed oil, salt, spices, sodium acetate, citric acid, ascorbic acid, vegetable bouillon, tomato puree, aroma), dumplings (water, buns (wheat flour, water, yeast, salt), onions, egg, wheat flour, milk powder, sunflower oil, salt, parsley, spices), venison ragout (venison, vegetable bouillon, salt, vegetable oil)
Aelpler Makkaronen	Pasta (durum wheat flour, water, egg, salt), water, potatoes, onion, bacon, milk powder, cheese, vegetable oil, salt, modified starch, vinegar, wheat flour, aroma, spices e.g. white pepper, garlic, sugar
Mashed potatoes, kale and sausage	Potatoes, kale, pork, water, onion, milk, salt, dextrose, preservatives, antioxidants, sodium glutamate, vegetable oil, dispersants, flavours, colorant, wheat protein, soya protein, starch, glucose syrup, spices, malt dextrin, stabilizer, milk yeast, vinegar, mustard seed, herbs, wheat flour, food acids, sugar

Lentil stew with dumplings	Lentil stew (lentils, water, bacon, smoked pork, wheat flour, mustard, onion, beef bouillon, modified starch, vegetable oil, vinegar, salt, aroma, pepper, marjoram, bay leaf, thyme), dumplings (buns (wheat flour, water, yeast, salt, vegetable oil), water, egg, vegetable oil, cream, salt)
Filled dumplings with sauerkraut	Dumplings (potatoes, wheat flour, egg, salt), filling (sausage (beef, bacon, pickling salt, stabilizer, spices), smoked bacon, pork, dried onions, garlic, parsley, marjoram, pepper), sauerkraut (sauerkraut, water, smoked pork, lard, wheat flour, salt, dried onions, beef bouillon, caraway, spices)
Goulash with sausages and potatoes	Potatoes, water, frankfurter, onions, bell pepper, lard, tomato puree, smoked pork, salt, spices, herbs, dextrose, yeast extract, starch, wheat flour, pepper
Salmon with potatoes and sauce	Potatoes, salmon, herb sauce (water, cream, milk powder, modified starch, salt, malt dextrin, yeast, fish powder, sugar, shrimp powder, lactose, vinegar, dextrose, spices, chives, white wine powder), carrots
Salmon with pasta and vegetables	Pasta (durum wheat flour, water, egg), sauce (tomato, water, salmon, olive oil, cream, onion puree, garlic puree, basil, milk, fish stock, salt, sugar, modified starch, stabilizer, citric acid, ascorbic acid, aroma, preservative, colorant, thickener, curry, pepper, yeast extract), salmon fillet, zucchini, cherry tomatoes, red onions, mushrooms
Salmon with pasta and spinach	Pasta (water, durum wheat flour), salmon, water, crème fraiche, spinach, cheese, onion, vegetable oil, wheat flour, garlic, salt, malt dextrin, yeast extract, carrots, celery, soya sauce, fructose, spices, aroma
Catfish with ratatouille and rice	Rice (water, rice, sunflower oil, herbs, salt), ratatouille (tomatoes, eggplant, zucchini, onion, bell pepper, water, bouillon, wheat flour, garlic, salt, sugar, modified starch, herbs), catfish fillet
Pollack with rice	Vegetable sauce (water, sour cream, carrots, celery, white root, onion, vegetable oil, modified starch, milk protein, thickener, fish bouillon, salt, dill, spices), rice (rice, wild rice, salt), Pollack

Pasta with spicy tomato sauce	Sauce (tomatoes, water, onions, bell pepper, ketchup (tomatoes, sugar, salt, modified starch, vinegar, spices), tomato puree, wheat flour, bouillon (salt, starch, vegetable oil, aroma, spices, onion, carrots, parsley), olive oil, spices, garlic, sugar, salt, sodium acetate, citric acid, ascorbic acid, aroma, salt, spices), pasta (durum wheat flour, egg, dried egg white)
Pasta with tomato-mozzarella sauce	Pasta (durum wheat flour, egg), tomatoes, tomato puree, mozzarella, cream, olive oil, modified starch, spices, fructose, salt, yeast extract

Table S2. Ingredients of the newly developed ready meals

Food names	Ingredients
Chicken with rice and vegetables	Chicken breast fillet (marinated with lingonberry juice and black pepper), rice, broccoli, cauliflower, carrots, red bell pepper sauce (water, cream, milk, red bell pepper, shallot onion, rape seed oil, modified starch, salt, aroma, sugar, stabilizer, antioxidants, spices (chili, white pepper))
Pork with mashed potatoes, carrots	Mashed potatoes (potatoes, water, cream, milk powder, butter, salt, white pepper), pork (pork, breadcrumbs, egg, water, rapeseed oil), mushroom sauce (water, buttermilk, mushrooms, modified starch, butter, vegetable oil, onion, milk powder, cream, aroma, spices, yeast extract, salt, glucose, colorant), carrots
Pork with mashed potatoes, broccoli	Mashed potatoes (potatoes, water, cream, milk powder, butter, salt, white pepper), pork (pork, breadcrumbs, egg, water, rapeseed oil), mushroom sauce (water, buttermilk, mushrooms, modified starch, butter, vegetable oil, onion, milk powder, cream, aroma, spices, yeast extract, salt, glucose, colorant), broccoli
Lamb with sauce, rice and vegetables	Rice, lamb fillet, eggplant, zucchini, bell pepper, mushrooms, red wine sauce (red wine, crème fraiche, rosemary, garlic, salt, pepper, modified starch), basil pesto, onion
Salmon with pasta and cauliflower	Salmon, pasta, cauliflower, carrots, green beans, mushroom sauce (milk, water, cream, mushrooms, modified starch, salt, stabilizer, glucose syrup, aroma, yeast extract, sugar, chicken fat, spices, antioxidants, colorant)
Salmon with potatoes and broccoli	Salmon, potatoes, broccoli, white wine sauce (fish broth, white wine, crème fraiche, dill, modified starch), mushrooms, salt, pepper, garlic
Pasta with spinach-ricotta filling	Pasta (wheat flour, water, spinach, ricotta, mozzarella, breadcrumbs, egg, salt, spice, rapeseed oil, starch, aroma, garlic, onion, nutmeg, pepper), tomato sauce (tomato, water, onion, tomato puree, rapeseed oil, starch, salt, vegetable bouillon, sugar, garlic, parsley, basil, pepper), tomato, mozzarella, hard cheese, spinach, pine nuts

Table S3. Definition of the categories used for classifying the collected Austrian convenience meals

Category	Definition and some examples
Soups	*Soup meals were either ready-to-heat or water has to be added prior to heating.* Examples: mushroom cream soup, chicken soup with noodles and vegetables, potato cream soup, minestrone, goulash soup, bean soup, tomato soup, soup with semolina dumplings, Asian soup with noodles
Pasta dishes	*Meals containing pasta as main component (e.g. spaghetti, tortellini, ravioli, gnocchi or spaetzle), stored either frozen, cooled or at room temperature, some of them only had to be re-heated, others were dry products which needed added water and/or oil prior heating.* Examples: Asian pasta dishes, fried noodles, pasta in spinach sauce, macaroni in cheese sauce, pasta with vegetables and tomato sauce, pasta Bolognese, pasta Carbonara, spaetzle with ham and cream, spaetzle with cheese, lasagne
Meat meals	*Meals which contained meat as main component (beef, pork, veal, poultry and/or venison) with or without side dishes.* Examples: Chicken with pasta, Sausages with gravy, Asian chicken curry with rice, Venison ragout with dumplings, Boeuf stroganoff, Minced meat with mashed potatoes, Chicken with bell pepper sauce, Viennese escalope filled with cheese and ham, prime boiled beef with spinach and roasted potatoes
Pizzas	*Ready-to-heat pizzas were stored either frozen or cooled including tartes flambées and baguettes.* Examples: Diavolo, Provinciale, Cardinale, Tonno, Margherita, Hawaii, Prosciutto, Vegetable

Sweet meals	*Sweet meals replacing a main dish, excluding desserts, which were either ready-to-heat or have to be prepared by adding water, milk and/or oil prior heating.* Examples: sugared pancakes with/without raisins, curd cheese dumplings, poppy-seed noodles made from potatoes, dumplings filled with strawberries or apricots or nougat, yeast dumpling filled with plum jam
Cold meals	*Cold ready-to-eat meals like e.g. sandwiches or wraps, which were offered at retailers.* Examples: Cheeseburger, Hamburger, Hot Dogs, Sandwiches with different fillings (eggs, cheese, ham, salami)
Salads	*Ready-to-eat salads with or without dressing, stored at cool temperature and offered at retailers.* Examples: Cucumber salad, bean salad, Mexican salad, potato salad, Chinese salad, noodle salad, salad with tomatoes and mozzarella, carrot salad
Savoury dumplings	*Savoury dumplings with various fillings which were either ready-to-heat or have to be boiled in hot water.* Examples: meat dumplings, Tyrolean dumplings, ham dumplings, sausage dumplings
Meals with potatoes, legumes or grains	*Meals with potatoes, legumes or other kinds of grain as main component (expect meals with pasta).* Examples: potato goulash, chili con carne, beans and ham, rice with meat, wok, paella, couscous
Fish meals	*Meals which contained fish (e.g. salmon, trout) as main component.* Examples: salmon with pasta, spinach and cheese sauce, catfish in tomato sauce with rice
Other meals	*Meals which are not able to be classified to one of the other meal types.* Examples: fried cheese, strudel with vegetables and sauce, mushroom sauce with dumplings

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LIST OF FURTHER PUBLICATIONS

Articles in international peer-reviewed journals:

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KANZLER S., MANSCHEIN M. & WAGNER K.-H.: Fat content and Fatty acid pattern of European Ready Meals. International Congress of Nutrition, 04.-09.10.2009, Bangkok, Thailand (poster presentation)

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Analytical Methods

The nutrient composition of European ready meals: Protein, fat, total carbohydrates and energy

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ABSTRACT

Despite the increasing social importance of ready meals, only few studies have been conducted on their nutrient composition.

Therefore, 32 chilled, frozen and heat-treated ready meals (only main dishes) from the continental European market were analysed for protein, fat, total carbohydrate and energy.

Half of the meals were nutritionally imbalanced by providing elevated fat (>30% of energy) and low carbohydrate levels (<50% of energy). Protein was generally above recommendations and ranged from 8.0 to 47.2 g per serving. The inter-package variation was high, reaching 19.04 ± 2.90 g/package for fat.

After proposing understandable guidelines to improve nutritional quality for the food industry, seven "nutritionally optimised" ready meals were created at the European level and analysed, however success was limited.

If product labelling is to be useful for consumers, our results also indicate a need for better quality control to reduce the differences between content and labelling.

1. Introduction

Over the past years, the importance of ready meals in the food markets has been growing steadily (Olsen, Sijtsema, & Hall, 2010). Driven mainly by convenience, more and more consumers prefer the easy-to-prepare ready meals to traditional home cooking. Major reasons for this include feeling time is scarce, more working women, variable family eating times, lack of cooking skills or dislike of cooking, and a growing number of small- and single-households (De Boer, McCarthy, Cowan, & Ryan, 2004; Jabs & Devine, 2006). This is in spite of the fact that ready meals are associated with poor taste and low nutritional value (too fatty/too salty) (Costa, Schoolmeester, Dekker, & Jongen, 2007).

Only a few regional studies have been conducted regarding the nutrient composition of ready meals currently available Europe-wide (Grübl-Knosp, Kiefer, Dieminger, Nester, & Stüger, 2009; Leighfield, Ghebremeskel, Doyle, & Crawford, 1993; Voedsel en Waren Autoriteit, 2006). For instance, the nutrient contents of German convenience foods have been estimated by recipe simulation using nutrient content declared on the label and listed ingredients (Alexy, Sichert-Hellert, Rode, & Kersting, 2008). In the UK, a processed food databank including on-pack levels of sodium, fat, sugar, and other nutrients from various processed foods, including some ready meals, has been established (Food Standards Agency, 2006, 2008). Most of the scientific literature, however, is focused on consumer attitudes (Geeroms, Verbeke, & Van Kenhove, 2008; Mahon, Cowan, & McCarthy, 2006).

To the best of our knowledge, no studies using laboratory methods to assess the nutritional composition of continental European convenience foods and ready meals have been conducted. The macronutrient contents of ready meals are of particular interest since total fat intake has been reported as high, and carbohydrates intake too low, across the European population (Elmadfa, 2009).

The EU-funded project "Double Fresh" (project No. FOOD-CT-2006-23182) aimed to assess and improve overall nutritional quality of convenience foods. To this end, ready meals from Central and Northern Europe as well as from the Benelux countries were analysed for their energy, protein, fat and carbohydrates.

Since prepared ready meals are intended to function as complete meals, including protein (fish or meat), starch (e.g. potato), vegetables and in many cases, a sauce, a secondary aim was to compare the results obtained with the nutrient recommendations for adults. After analysing a range of ready meals that are currently available on the continental European market, Double Fresh also

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established some basic nutritional guidelines, specifically addressed at the food industry, with the aim of improving product nutritional values. These guidelines were easy to understand since the major decision makers in the food industry are not nutrition experts.

With the help of these guidelines, food industry partners in Double Fresh developed new ready meals, which were optimised not only with regard to nutritional composition but also improved sensory attributes, food safety, and packaging to extend shelf life. Finally, these meals were analysed based on the same parameters and the nutritional value of the meals before and after compared.

2. Materials and methods

2.1. Samples

A total of 39 ready meals (32 plus 7) from seven European countries were analysed in two sampling rounds. Ready meals (32), currently offered to European consumers in supermarkets, were sampled. Seven of these meals were nutritionally optimised and analysed using the same parameters.

Food industry partners in Double Fresh provided 19 of ready meals (12 in round 1 + 7 optimised in round 2). The Austrian ready meals (20) from the most important brands were sampled in supermarkets (leading markets as well as discount markets).

The main criteria for selection were sales figures and the food type. Meals sold most frequently have the greatest impact on consumer health. Since food choices differ throughout Europe, we included typical, commonly purchased, regional meals (provided by our industrial cooperation partner).

From our point of view, improvement of frequently consumed ready meals is of much higher relevance than providing healthier alternatives, which are purchased less frequently.

Since the diversity of production and distribution solutions of ready meals are increasing, a precise definition is important. According to Costa, Dekker, Beumer, Rombouts, and Jongen (2001) ready meals are "meal solutions that have been produced away from home for in-house consumption", which can be either purchased at retailers or takeaway shops or supplied by home delivery systems. All analysed ready meals met this definition of home meal replacements.

The ready meals investigated comprised a main dish typically a fish or meat portion, a starchy component, such as rice/potatoes/noodles, a vegetable portion and/or a sauce, in single portion containers, designed to fully, and quickly, replace the main course of a homemade meal. No additional ingredients were necessary for preparation.

Most of the meals were packaged in a plastic tray, with one or more chambers for microwave heating, and were either chilled (25 + 7), frozen (5 + 0) or stored at room temperature (2 + 0).

The majority of the meals (31 + 5) were so-called ready-to-heat meals, which are prepared entirely by the food manufactures and the consumers have only to heat the meals prior to consumption. Three meals included raw salmon fillet or a raw chicken breast as well raw vegetables and, therefore, required additional microwave cooking before consumption (ready-to-cook meals, 1 + 2). In this study, no sweet dishes or calorie controlled meals were included.

2.2. Instruments

A Mixer B-400 (Büchi, Flawil, Switzerland) and a freeze-dryer Lyolab B (Inula, Vienna, Austria) were used to homogenise and lyophilise the meals, respectively. An accelerated solvent extraction system (ASE® 100, Dionex, Vienna, Austria) was used to determine total fat content. In order to measure the nitrogen content, a digestion unit B-426 with control B-436 and distillation B-316 units (Büchi) was used, and a STAT Titrino 718 (Metrohm, Herisau, Switzerland) for the titration. A forced draft oven and a muffle furnace (Heraeus Instruments, Hanau, Germany) were used to determine dry matter and ashes.

2.3. Reagents and solvents

All chemicals used were obtained from Riedel-de Haën (Seelze, Germany). Petroleum ether of analytical grade was purchased from E. Merck (Darmstadt, Germany) and boric acid (purity 99.5%) from Sigma–Aldrich (Vienna, Austria).

2.4. Sample preparation

Most of the ready meals were heated in a microwave, on the final day of shelf life, as specified on the label by the manufacturers including time and power (30 + 7). One meal was heated on an electric hob and the other in an electric oven.

After preparation, the meals were weighed, cooled on dry ice, homogenised, and stored at −80 °C under nitrogen until further analyses (not longer than four weeks).

The edible portion of each meal was 100%. The sample size was always one pack, which in most cases was equivalent to one serving.

Two sub-samples per meal were taken from the Austrian meals (20) and five sub-samples from all the remaining European ready meals (12 + 7). These were taken from the same batch and analysed in duplicate. If the relative standard deviation (RSD) was larger than 3%, the analyses were repeated.

2.5. Methods

Total protein was determined by the Kjeldahl method (Matissek & Steiner, 2006). The titration was done with a standardised hydrochloric acid (0.1 mol/l) until a pH-value of 6.10 was reached. To calculate protein from nitrogen, the factor 6.25 was used (Greenfield & Southgate, 2003).

Total fat was extracted with an ASE® 100 system after hydrolysis with hydrochloric acid (25% w/w) using the modified method of Weibull-Stoldt (Matissek and Steiner, 2006; Wagner, Plasser, Proell, & Kanzler, 2008). The amount of total fat was quantified gravimetrically.

Dry matter and ash were analysed gravimetrically as previously described by Matissek and Steiner, (2006). The amount of total carbohydrates was obtained by subtracting the amounts of water, protein, total fat and ash from 100.

Energy content refers to the content of crude energy, derived by calculation from energy-yielding constitutes using energy conversion factors, i.e. 17, 37, and 17 kJ/g for protein, fat, and total carbohydrates, respectively (Greenfield and Southgate, 2003).

The accuracy of the analyses was verified using the certified Standard Reference Material® 1846 (National Institute of Standards and Technology, Gaithersburg, USA). The recovery rates obtained were 99.1%, 98.5%, 99.4% and 105.1% for the analyses of protein, fat, dry matter and ash, respectively.

The methodś reproducibility were verified by calculating RSD for a control sample (noodles with a zucchini tomato sauce) ten times in one day, alongside the other samples. The mean values for protein, fat, dry matter and ash were 4.32, 1.68, 31.25 and 1.28 g per 100 g control food sample. The RSDs from one day were 1.1%, 2.4%, 0.3% and 3.1% and between days 1.9%, 2.5%, 0.4% and 3.3% for the analyses of protein, fat, dry matter and ash, respectively.

2.6. Data presentation and comparison with international dietary recommendations for nutrient and energy intakes

The data obtained from the analyses were calculated per 100 g as well as per serving and presented as means, minima and maxima (Tables 1 and 2).

Data were also compared with international dietary recommendations (RDIs) (Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährungsforschung, & Schweizerische Vereinigung für Ernährung, 2000; Elmadfa & Kornsteiner, 2009; Eurodiet, 2000; Health Council of the Netherlands, 2001; Mann et al., 2007; Nordic Council of Ministers, 2004; World Health Organisation, 2003) to evaluate the quality of the nutrients provided for the consumer. For the nutritional assessment, only the RDIs from the three European regions included in this study (Central Europe, Northern Europe, Benelux countries) and the ones from the EU regulation No. 1169/2011, were used. Given a meal should provide consumers with, on average, 30% of recommended amounts of energy and nutrients (Celnik, Gillespie, & Lean, 2012; Deutsche Gesellschaft für Ernährung, 2008; Nordic Council of Ministers, 2004), the data obtained for analyses per serving were compared with 30% of RDIs for males and females between 30 and 50 years of age with a sedentary lifestyle (Supplemental data table s2).

2.7. Statistical analyses

To determine whether differences among the ready meals, depending on ingredients (food type), were significantly different, data were tested on normal distribution and then analysed by one-way analysis of variance (ANOVA) followed by Bonferroni post hoc test for homogenous or Dunnet-T3 test for non-homogeneous variances, or the Students t-test. Statistical differences were considered significant at $p < 0.05$. IBM SPSS version 20.0 for Microsoft Windows was used.

3. Results and discussion

3.1. Composition of the ready meals currently available on the continental European market ($n = 32$)

Approximately 63% ($n = 20$) of the 32 ready meals contained meat (40%, 8 white meat, 30%, 6 pork and 30%, 6 beef or venison). A further 16% (5) contained meat products such as sausage or bacon, and 16% (5) contained fish, which was salmon (Salmo salar), catfish (Pangasianodon hypophthalmus) or Pollack (Pollachius virens). The remaining 6% (2) were vegetarian meals. The starchy component in 41% (13) of the ready meals analysed was rice; 22% (7) contained 232 potatoes, 22% (7) noodles and 16% (5) of the meals included dumplings, spaetzle (soft noodles made of wheat flour, eggs and salt) or similar. Nearly all the meals contained a sauce (94%, 30), and half of them (53%, 17) different vegetables, legumes or fruits in an amount of more than 10% (w/w).

Of those ready meals, five originated from Northern Europe (Finland and Norway), five from the Benelux countries (The Netherlands and Belgium) and 22 from Central Europe (Switzerland and Austria).

Macronutrient content, water and energy are shown in Table 1. The detailed ingredient lists according to the producerś labels can be found in the Supplemental data Table S1.

3.1.1. Protein

Goulash with sausages and potatoes, a typical Austrian meal, which only contained 10% (w/w) Frankfurter sausages, had the lowest protein content (<3 g/100 g), whereas roasted pork with dumplings, venison ragout with dumplings and beef goulash with spaetzle had the highest (>10 g/100 g). This is because the meat portions of these meals exceeded 19% (w/w) of the entire dish, and the dumplings and spaetzle contained eggs as an additional protein source.

3.1.2. Fat

Pasta with spicy tomato sauce, catfish with ratatouille as well as the chicken with carrots and peas had the lowest fat contents of the meals analysed (<1 g/100 g). This can be explained by the fact these meals contained only low-fat fish or meat, no high-fat sauce, and vegetables. Minced meat with mashed potatoes and roast pork with dumplings had the highest fat contents of the meals analysed (>9 g/100 g). Both are typically Austrian meals characterised by the use of pork, particularly those parts of the animal high in fat.

Another high-fat meal was salmon with pasta and spinach. Presumably, this was not only due to the salmon included (14% (w/w) of the meal), but also the sauce, which was made of crème fraiche, vegetable oil and high-fat cheese (>40% fat in dry matter). In comparison, the vegetarian pasta with spicy tomato sauce included only tomato sauce with salt and spices and, therefore, had the lowest fat content of all. These results clearly imply that ready meal producers should be made more aware of the fact that sauces have a considerable impact on total fat and, consequently, energy content of the meal.

3.1.3. Total carbohydrates

Four meals with potatoes had the lowest carbohydrate content: pork with cabbage; mashed potatoes, kale and sausage; salmon with potatoes as well as minced meat with mashed potatoes (<10 g/100 g). The highest carbohydrate content was found in pork in spicy tomato sauce. This meal also had the highest energy, a high fat content, and the lowest water content (Table 1). With reference to the list of ingredients (Supplemental data Table S1), this can be explained by the high sugar content, lard and vegetable oil added to the tomato sauce.

3.1.4. Water and energy

Brun lapskaus, a Norwegian meat stew, catfish with ratatouille, chicken with carrots and peas as well as the pork with cabbage had the lowest total energy (<400 kJ/100 g). These four meals also had the highest water content (>80 g/100 g) and included larger servings of various vegetables and only low-fat sauces. The highest energy was found in the following four meals: pork in spicy tomato sauce; chicken-risotto with mango sauce; salmon with pasta and spinach (which also included the above mentioned high-fat cheese sauce) and the roast pork with dumplings (>700 kJ/100 g). These meals contained either fatty sauces with high-fat milk-products, cheese or lard, or larger meat portions.

3.1.5. Differences between the meals according to the food type

Between meat-based, fish-based and vegetarian meals, no significant differences in water, fat, protein, total carbohydrate and energy were found.

Regarding the starchy side dish included (rice $n = 13$, potatoes $n = 7$, noodles $n = 7$, dumplings/spaetzle $n = 5$), meals with potatoes contained significantly more water (78.9 g/100 g) than meals with rice (70.7 g/100 g; $p = 0.003$), noodles (71.9 g/100 g; $p = 0.043$) or dumplings/spaetzle (69.7 g/100 g; $p = 0.010$). However, those meals with potatoes had significantly less total carbohydrates (9.8 g/100 g) than the meals with rice (18.1 g/100 g; $p = 0.000$) and noodles (15.8 g/100 g; $p = 0.028$). According to the German food composition database (Bundeslebensmittelschlüssel), cooked and peeled potatoes contain 80.4 g of water followed by cooked white rice with 73.4 g and cooked noodles with 66.7 g per 100 g

Table 1
Protein, fat, total carbohydrates (CHO), water and energy per 100 g edible portion of European ready meals (n = 32).[a]

Food names (number of sub-samples taken)	Protein (g/100 g)			Fat (g/100 g)			Total CHO[b] (g/100 g)			Moisture[c] (g/100 g)			Energy[d] (kJ/100 g)		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
Chicken with rice and curry sauce (5)	5.8	5.2	6.4	2.5	2.3	2.6	22.5	21.0	23.8	67.7	66.8	68.6	572	558	590
Chicken risotto with mango sauce (5)	6.4	6.2	6.8	8.2	7.0	9.4	21.1	20.0	22.5	62.6	61.5	63.8	773	746	795
Chicken with carrots, peas, potatoes (5)	5.6	5.3	5.8	0.9	0.9	1.0	11.8	11.4	12.1	80.5	80.0	81.3	329	314	336
Chicken risotto (5)	5.6	5.1	6.4	2.0	1.9	2.2	20.2	19.7	20.8	70.4	70.3	70.8	513	507	516
Chicken curry with rice (2)	4.8	3.8	5.9	2.9	2.6	3.2	20.1	19.0	21.3	70.6	70.4	70.9	533	523	542
Asian rice dish with chicken (2)	6.9	6.6	7.2	3.9	3.9	4.0	18.0	17.8	18.1	69.3	69.2	69.4	568	566	569
Chinese chicken with rice (2)	6.7	6.2	7.2	2.0	1.9	2.1	14.0	12.6	15.5	75.1	74.3	75.9	424	412	437
Chicken with mushrooms and rice (2)	7.2	7.0	7.5	3.7	3.6	3.8	11.7	11.2	12.2	76.1	75.7	76.5	459	452	467
Brun lapskaus (5)	5.2	4.4	5.7	1.4	1.2	1.7	10.2	9.7	10.4	81.7	81.4	82.5	311	297	322
Pork in spicy tomato sauce with rice (5)	5.3	4.9	5.8	5.9	5.1	6.4	28.7	27.9	30.2	58.5	57.8	58.9	796	787	808
Roast pork with dumplings (2)	12.4	11.3	13.5	9.0	8.6	9.4	10.6	10.2	11.1	65.6	64.6	66.7	723	697	749
Minced meat with mashed potatoes (2)	5.2	5.1	5.2	9.5	9.5	9.6	9.8	9.7	9.9	73.8	73.6	73.9	606	605	608
Fillet of pork with rice (2)	7.6	7.1	8.2	5.6	5.3	5.9	14.1	13.5	14.7	71.0	70.7	71.4	575	564	586
Pork with cabbage and potatoes (2)	5.1	4.1	6.1	4.3	4.3	4.3	7.7	7.4	8.0	81.1	80.4	81.8	376	364	389
Kebab meat with rice and sauce (5)	5.7	5.2	6.0	6.5	6.1	7.0	19.4	18.7	19.8	66.8	66.5	67.6	665	644	679
Beef stroganoff with rice (5)	6.5	6.4	6.8	1.4	1.2	1.6	15.0	14.8	15.1	76.1	75.7	76.4	418	409	425
Beef goulash with spaetzle (2)	10.1	10.0	10.2	3.8	3.7	4.0	14.6	14.4	14.8	69.9	69.5	70.3	561	551	572
Pasta with sauce Bolognese (2)	6.4	6.4	6.4	5.0	4.9	5.2	15.5	14.8	16.2	71.8	71.3	72.4	558	552	564
Beef roulade with pasta (2)	6.8	6.7	7.0	4.3	4.3	4.4	11.8	11.5	12.2	75.3	75.1	75.4	478	476	480
Venison ragout with dumplings (2)	10.2	9.0	11.4	3.1	3.1	3.1	13.4	13.2	13.6	71.7	71.2	72.2	517	500	533
Aelpler Makkaronen (5)	4.8	4.8	4.9	5.1	5.1	5.3	16.6	16.2	17.1	71.6	71.1	72.0	555	547	562
Mashed potatoes, kale and sausage (5)	4.1	3.9	4.3	6.1	5.9	6.3	9.4	9.2	9.5	78.8	78.5	79.0	452	446	458
Lentil stew with dumplings (2)	6.8	6.6	6.9	5.0	4.7	5.2	16.8	16.0	17.7	69.8	69.0	70.6	584	576	593
Filled dumplings with sauerkraut (2)	4.5	4.5	4.6	8.3	7.8	8.7	14.2	13.8	14.6	71.3	71.1	71.4	623	611	635
Goulash with sausages and potatoes (2)	2.3	2.1	2.4	7.4	7.4	7.4	10.3	10.2	10.4	78.1	77.9	78.3	487	484	490
Salmon with potatoes and sauce (5)	6.9	6.5	7.4	3.9	3.2	4.8	9.7	9.4	10.3	78.4	77.6	79.3	426	398	457
Salmon with pasta and vegetables (5)	5.9	5.7	6.2	4.1	3.7	4.9	11.7	11.0	12.0	77.0	76.1	77.4	450	438	473
Salmon with pasta and spinach (2)	7.1	6.5	7.6	9.5	9.4	9.6	16.5	16.0	17.0	65.5	65.2	65.7	751	745	757
Catfish with ratatouille and rice (2)	4.6	4.4	4.9	0.8	0.7	0.8	12.6	12.0	13.2	80.5	80.3	80.8	321	318	324
Pollack with rice (2)	3.1	3.1	3.2	3.4	3.1	3.6	18.1	17.7	18.4	73.8	73.3	74.3	484	470	498
Pasta with spicy tomato sauce (2)	4.0	3.8	4.1	0.7	0.6	0.9	22.0	21.8	22.1	71.7	71.6	71.9	468	464	473
Pasta with tomato-mozzarella sauce (2)	5.4	5.3	5.6	6.0	5.9	6.2	16.3	16.0	16.6	70.4	70.4	70.4	592	589	595

[a] Results are presented as means, minima and maxima. From each sample (n) either two or five sub-samples were taken from the same batch. Where two sub-samples were taken the mean is equal to the median.
[b] Calculated by difference (total CHO = 100 – moisture – protein – fat – ash).
[c] Calculated by difference (moisture = 100 – dry matter).
[d] Calculated using the general Atwater factors, i.e. 17 kJ/g for protein, 37 kJ/g for fat and 17 kJ/g for total CHO.

Table 2
Protein, fat, total carbohydrates (CHO), water and energy per 100 g edible portion of the newly developed ready meals ($n = 7$).[a]

Food names (number of sub-samples taken)	Protein (g/100 g)			Fat (g/100 g)			Total CHO[b] (g/100 g)			Moisture[c] (g/100 g)			Energy[d] (kJ/100 g)		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
Chicken with rice and vegetables (5)	2.9	2.7	3.1	8.5	8.1	8.8	11.2	10.9	11.5	76.3	76.0	76.7	443	432	452
Pork with mashed potatoes, carrots (5)	5.5	4.8	5.9	6.4	6.0	6.6	11.9	11.2	12.6	74.9	73.8	76.1	514	479	534
Pork with mashed potatoes, broccoli (5)	6.0	5.7	6.4	6.9	6.7	7.2	11.7	10.9	12.1	73.9	73.0	75.3	541	511	562
Lamb with sauce, rice and vegetables (5)	6.0	5.6	7.0	7.3	6.8	7.7	13.6	13.3	13.8	72.2	71.9	72.7	577	564	604
Salmon with pasta and cauliflower (5)	6.6	6.4	6.8	9.0	8.6	9.5	13.1	12.5	13.7	70.3	69.9	70.7	619	614	626
Salmon with potatoes and broccoli (5)	5.2	4.8	5.6	7.3	7.0	7.6	10.6	10.0	11.1	75.8	74.8	76.7	496	474	522
Pasta with spinach-ricotta filling (5)	2.9	2.6	3.2	5.6	5.2	6.0	20.3	18.9	21.8	69.6	67.3	71.6	546	509	589

[a] Results are presented as means, minima and maxima. From each sample (n) five sub-samples were taken from the same batch.
[b] Calculated by difference (total CHO = 100 – moisture – protein – fat – ash).
[c] Calculated by difference (moisture = 100 – dry matter).
[d] Calculated using the general Atwater factors, i.e. 17 kJ/g for protein, 37 kJ/g for fat and 17 kJ/g for total CHO.

edible portion, whereas the content of carbohydrates is only 15.0 g for potatoes, 23.4 g for rice and 26.1 g per 100 g for noodles. Since these ingredients are the major carbohydrate sources of the meals, these differences were also reflected in the entire meals.

The assumption that ready meals with vegetables ($n = 17$) have significantly more water (74.7 vs. 70.2 g/100 g; $p = 0.019$) and significantly less energy (481 vs. 584 kJ/100 g; $p = 0.017$) than those without vegetables ($n = 15$) was confirmed. Importantly, this reinforces the fact that the addition of vegetables to a meal significantly reduces energy content.

3.2. Inter-package variation of nutrient composition

Large variations in the nutrient compositions between packages of the same batch were shown. This might be due to the filling process, which led to different amounts of meal components. For example, the first package of chicken curry with rice contained 200 g of chicken meat and curry sauce and 187 g of rice. The second package contained 15% less meat and sauce, and 17% more rice. This inaccuracy led to differences in macronutrients and energy resulting in a high inter-package variation. Between the five different packages of salmon with potatoes that were considered for analyses, the sauce ranged from 67 g to 100 g. This led to a high variation of the nutrients, particularly the fat content (19.04 ± 2.90 g/package). On the other hand, there were also examples for a more precise filling process found, such as the beef roulade and the beef stroganoff. The EU regulation No. 1169/2011 will require mandatory nutrient labels for all pre-packed foods, which could raise questions about quality control, in particular filling processes, to ensure trustworthy labels on packages.

3.3. Comparison of the analysed data with nutritional labelling given on the packages

Since nutritional labels were found on all the ready meals investigated, comparison of the label data with the laboratory data was possible. Deviations from the label were calculated as percentages. An acceptable deviation of less than 10% was found for 19, 12, 11 and six ready meals with respect to energy, total carbohydrate, protein and fat (Fig. 1). Deviations greater than 25% were found for energy in five meals and for fat in 12 meals. The highest deviation for energy (on-pack vs. analysed) was 30%. There were two meals where the labelled fat exceeded the analysed values by 100%. This shows that the declaration of fat is far more questionable than the one for energy. Thus, besides accurate filling of the package, there is also a need for improved on-pack nutritional values to ensure trustworthy labels for consumers. Otherwise, the significance of mandatory nutrient labelling, as proposed in

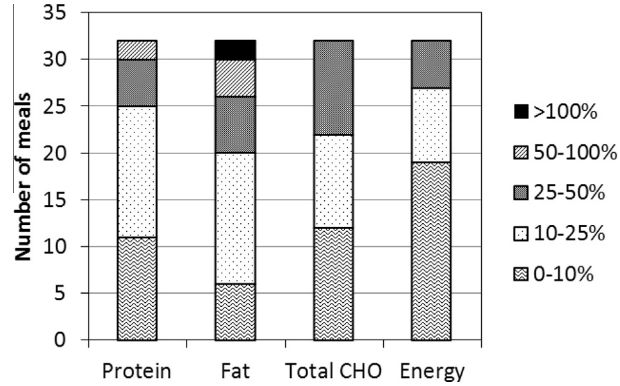

Fig. 1. Deviation of the on-pack labelled nutrient contents in comparison to the laboratory analysed data expressed as percentages ($n = 32$) CHO = Carbohydrates.

the EU regulation No. 1169/2011, remains questionable. Manufactures must implement all necessary measures to ensure reliable product labels.

3.4. Nutritional evaluation of the currently available ready meals (n = 32)

Ready meals are usually designed to replace one main course. Therefore, macronutrients and energy per serving were compared to 30% of daily dietary reference values (Table S2) for males and females. One serving was equivalent to the mealś package sizes, which ranged from 300 g to 500 g ($n = 30$). The package size of two meals was larger than one serving, thus, their portion sizes were estimated.

Total protein in the ready meals analysed varied from 8.0 g to 47.2 g per serving. Compared with the dietary allowances for one main meal, protein in 23 of 32 ready meals was between the upper and lower limits of protein intake (between 14 g and 28 g/serving). Thus, nine meals provided either too much or too little protein.

Fat ranged from 2.5 g to 34.0 g/serving. Less fat than recommended (<19 g/serving) was found in 19 out of 32 meals analysed. The total fat of another nine meals was higher than recommended (>25 g/serving). Since the Dutch fat recommendation is highest, only four meals exceeded the upper limit for females (>31 g/serving) and none for males (>40 g/serving).

Total carbohydrates including dietary fibres ranged from 25.4 g to 143.3 g/serving. Only one meal contained more carbohydrates than the recommended lower intake level for adults (>101 g/serving). Carbohydrate intakes from 25 meals were below recommendation (<69 g/serving).

Energy from the meals analysed ranged from 1123 kJ to 3978 kJ/serving. Compared to the recommendations for female adults with a sedentary lifestyle, only 6% of the meals exceeded the recommendations (>2910 kJ/serving). The latter contained even more energy than recommended for male adults with sedentary lifestyle (>3060 kJ/serving).

Taking energy of the meals into account, fat varied from 5.9%Energy (E) to 58.2%E and total carbohydrates from 25.1%E to 79.8%E. More than the generally recommended 30%E of fat, was found in 17 out of 32 ready meals. The reference value for the intake of total carbohydrates is generally defined as 50%E, which should be regarded as the lowest intake threshold. Hence, 18 out of 32 ready meals contained fewer carbohydrates than recommended.

In summary, these results indicate that the ready meals tested, on average, did not provide excess energy and fat. However, taking into account the low energy of the meals, the results clearly demonstrate that half of the meals were nutritionally imbalanced, providing elevated fat (>30%E) and low carbohydrate levels (<50%E).

3.5. Establishing easily understandable recommendations for the food producers to develop healthier meals

To address the problem of nutritionally unbalanced ready meals, Celnik et al. (2012) proposed the creation of nutritional standards for "healthy" ready meals, which would allow consumers to make an informed choice. Our approach, however, was to establish simple and basic nutritional guidelines for the food industry. To reach as many companies and retailers as possible, these guidelines were published in various continental European trade journals, either in print or online (e.g. Kanzler & Wagner, 2009). The guidelines are summarised in the online Supplement Table S3.

3.6. Nutrient composition of newly developed ready meals (n = 7)

One aim of Double Fresh was to create new, nutritionally balanced meals. These newly developed meals included four with meat (one chicken, two pork, one lamb), two contained fish (salmon) and one was designed for vegetarians. Side dishes were rice and noodles for two meals, and potatoes for three. All of the meals contained vegetables and a sauce. The ingredient lists are available in the Supplemental data Table S1.

Four meals were from Northern Europe (Finland and Norway), two from the Netherlands and one meal was obtained from Germany.

It was important that the food industry partners considered the nutritional recommendations (Table S3) when developing the new meals. Thus, all newly developed meals contained a vegetable portion. The values for energy, water and macronutrients in kJ or g/100 g edible portion are shown in Table 2.

The portion sizes of these meals varied from 360 g to 470 g ($n = 7$). Total energy per serving ranged from 1850 kJ to 2909 kJ. Analyses determined two of the new ready meals still contained more energy than recommended for females (<2340 kJ), but were within recommendations for males (<3060 kJ). Protein of four meals was within recommendations (15%E to 20%E); the other meals provided more protein than recommended (up to 33%E). Fat in five of the meals varied from 38%E to 42%E, which means only two meals met the recommended upper intake level of 30%E. Total carbohydrates in six of the meals were between 35%E and 45%E and, thus, still below the recommended lower intake level of 50%E.

As shown by these results, the implementation of guidelines was not wholly effective when considering macronutrients. Reasons for this include unchanged recipes with small vegetable portions (30 g) and the addition of high amounts of sauce (up to 100 g). Only the pasta with spinach-ricotta filling had an optimal distribution of macronutrients. This meal was vegetarian since the pasta contained only a tomato sauce, fresh tomatoes, spinach leaves, cheese and pine nuts.

Two major limitations of the meal reformulation were observed. First, no nutritional experts were directly involved in the process of modifying the recipes in the various company. Second, the focus of some ready meal producers was not only to optimise the nutritional value, but rather to "show" some improvements (e.g. by adding vegetables). Further, they were focused on extending the productś shelf life and optimising their sensory quality. When dealing with nutritional optimisation, it must be kept in mind that even the healthiest meals are only accepted when specific sensory attributes are appreciated such as appearance, flavour, texture and odour (Olsen, Menichelli, Sørheim, & Næs, 2012). Nonetheless, salt was successfully reduced in the new meals (Kanzler, Gruber, Lammer, Hartmann, & Wagner, 2014).

4. Conclusion

Our results indicate inaccuracies with packages filling and with on-pack nutrient labelling. Hence, mandatory nutritional labelling as proposed in the EU regulation No. 1169/2011, will only be useful for consumers, if additional food quality measurements are implemented by food manufacturers, and checked by food safety authorities.

Since the importance of ready meals is likely to persist, different ways of addressing the problem of nutritionally unbalanced meals should be discussed. Creating and offering consumers more ready meals with appropriate energy content, balanced macronutrient distribution and desirable sensory quality, would have a great impact on consumeŕs health.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodchem.2014.09.075.

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PAPER II

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Salt as a public health challenge in continental European convenience and ready meals

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Abstract

Objective: To assess the salt content of continental European convenience and ready meals.

Design: A multistage study in which, after laboratory analysis of the products' salt contents (*n* 32), new salt-reduced meals were developed through food reformulation. Additionally, a comprehensive survey of convenience meals from the Austrian market (*n* 572) was conducted to evaluate the salt contents of a wider product range.

Setting: Six continental European countries participated.

Subjects: No subjects enrolled.

Results: The salt contents of continental European convenience and ready meals mostly exceeded 1·8 g/100 g, which is 30 % of the targeted daily intake level; some contained even more than the recommended daily intake of 6 g. The highest salt contents were found in pizzas and pasta dishes, the lowest ones in sweet meals. Large variations in salt levels were found not only between and within meal type categories, but also between similar meals from different producers. In addition, our approach to develop new salt-reduced meals showed that a stepwise reduction of the ready meals' salt contents is possible without compromising the sensory quality.

Conclusions: To address the problem of hypertension and increased risk for CVD through high salt intake, a reduction of the salt levels in continental European convenience and ready meals is urgently needed, since they are providing a major part of the daily salt intake. Successful national-wide salt reduction strategies in the UK or Finland have already demonstrated the public health impact of this setting.

Keywords
Salt
Convenience products
Ready meals
Hypertension

Non-communicable diseases including CVD, diabetes, cancer and chronic respiratory diseases are the leading cause of death worldwide. Raised blood pressure as a major single risk factor for CVD is estimated to cause 7·5 million deaths per year (12·8 % of all global deaths)[1].

There is conclusive evidence that a high salt intake is associated with hypertension, which consequently increases the risk for CVD such as stroke or CHD[2–4]. To reduce blood pressure a limited salt intake is recommended and for adults should not exceed 6 g/d according to different expert committees[4–8] or 5 g/d according to the WHO[3].

The cost-effectiveness of salt reduction programmes to reach these intake levels and to prevent CVD has been demonstrated recently[9–13]. A saving of $US 10–24 billion in annual health-care costs with a population-wide reduced salt intake of 3 g/d has been estimated[10]. According to a recent WHO report, 'a reduced salt intake and salt content of food' is considered to be a 'best-buy' action that should be implemented as soon as possible to save lives by preventing diseases[1].

Besides the effects on blood pressure, a high salt intake may lead to the progression of renal disease, renal stones and stomach cancer and may be linked to the severity of asthma[2].

Despite these reports, the current average daily salt intake of most adult populations exceeds 6 g/d and in many, especially Asian, countries even 12 g/d. Also for children older than 5 years of age excessive salt intakes have been reported[14]. In Austria 47 % of women, 60 % of men, 72 % of girls and 78 % of boys (both aged 7–14 years) have salt intakes above 6 g/d[15].

In European and North American diets, most of the dietary sodium results from sodium chloride added to manufactured food (approximately 75 % of intake in the USA and the UK)[16,17]. The main contributors are cereals and cereal products (including bakery products, pasta, rice

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and breakfast cereals) as well as meat and meat products (including bacon, ham, sausages and meat dishes)[18–21]. Since the importance of convenience foods including fast foods, takeaways and ready meals is increasing steadily[22–24], the salt content of this product group has to be considered when assessing the daily salt intake. Particularly the salt contents of fast food and takeaway meals are alarmingly high[25–28]. The salt concentrations of convenience foods including ready meals, soups or pizzas that are available on the Australian and British market showed high variations within meals of the respective food groups (e.g. pizzas)[21,29–33]. The same was true for the salt content of fast foods, which varied not only by the type of food, but also by producer and country of origin[25].

The combination of food reformulation with improved food labelling and initiatives to raise consumer awareness has already led to successful national-wide salt reduction programmes, e.g. in Finland and the UK[34–36].

Since the market for convenience products is growing steadily in continental Europe, there is a strong need to assess salt in ready meals and to develop further strategies to lower current salt intake levels as a public health tool.

Our aim was to assess the salt content of continental European ready meals within the European research project 'Double Fresh'. The objective of the project was to raise the overall quality of these meals. Therefore experts from different food science areas and nutrition worked together with small- and medium-sized enterprises to improve sensory properties and nutritional composition and cover the food safety aspects of these meals (project no. FOOD-CT-2006-23182; www.doublefresh.eu).

To assess the salt content our investigations were divided into three sequenced sections. First, ready meals offered on the continental European market were analysed in the laboratory. In the second stage, our objective was to assist the food company partners in developing new salt-reduced products and to evaluate the process of meal reformulation. Hence, we established basic, easily understandable nutritional guidelines and further analysed the salt levels of the newly developed meals. In order to include a higher number of meals, we comprehensively evaluated the labelled salt contents of convenience foods sold by Austrian retailers.

Experimental methods

Samples

*Ready meals from the European market (*n *32)*

A total of thirty-two ready meals offered to European consumers in supermarkets were investigated.

All meals met the definition of home-meal replacements published by Costa *et al.*[37]. They represented main dishes comprising all typical components (a protein component such as meat/fish, a starchy component such as rice/potatoes/noodles, vegetables and/or a sauce). No addition of further ingredients was necessary in the course of preparation. The meals were chilled (*n* 25), frozen (*n* 5) or stored at room temperature (*n* 2).

Of the analysed ready meals, 63 % contained meat, 16 % were meat products (sausages or bacon) and 16 % contained fish (salmon, catfish or pollock). The remaining 5 % were vegetarian meals. The starchy component in 41 % of all analysed ready meals was rice, 25 % contained potatoes, 22 % noodles and 16 % of all meals included other components (e.g. dumplings). Nearly all meals contained a sauce and half of the meals different vegetables, legumes or fruits in an amount of more than 10 % (w/w). The detailed ingredient lists according to the producer labelling are presented in the online supplementary material, supplemental Table S1.

Twelve ready meals were provided from food industry partners of the 'Double Fresh' project. Of those ready meals five originated from the Scandinavian region, five from the Benelux countries and another two from Central Europe. The twenty Austrian ready meals from the most popular brands were sampled at retailers (leading markets as well as discount markets).

The main selection criteria were sales figures (available through personal contact with food companies) and the food type. Frequently sold meals are often eaten and hence have a greater impact on consumers' health than other meals.

*Newly developed ready meals (*n *7)*

As already described the food industry partners developed seven supposedly salt-reduced meals, which were analysed for their salt contents. All of these meals were chilled and met the above-mentioned definition of home-meal replacements. From these meals, four contained meat, two meals fish (salmon) and one meal was vegetarian. As side dish rice was chosen for two meals, noodles for two meals and potatoes for three meals. All of the analysed optimized meals contained vegetables and a sauce. The lists of ingredients are available in supplemental Table S1.

*Convenience foods from the Austrian market (*n *572)*

For a comprehensive survey of convenience foods from the Austrian market, ready meals that met the above-mentioned criteria but also main dishes without accompaniment, soups, hot sweet dishes (except for desserts), cold sandwiches and salads were sampled one year after the laboratory analyses. All meals were ready-made and only had to be heated before consumption either without adding any further ingredients or with adding some water, milk and/or oil. Fourteen of the twenty laboratory-analysed meals were still available on the market and thus included in the survey.

The collected ready meals were categorized into the following meal types: soups, pasta dishes, meat meals, pizzas, sweet meals, cold meals, salads, savoury dumplings, meals with potatoes/legumes/grains, fish meals and other meals.

The definitions of each category including some examples can be found in the online supplementary material, supplemental Table S2.

Analyses

Sample preparation

Ready meals were heated with a microwave oven on the respective last days of shelf life as instructed on the packages (time and wattage). One meal was heated with an electric cooker and another one in the oven.

After preparation the meals were weighed, immediately cooled on dry ice, homogenized (Mixer B-400; Büchi, Flawil, Switzerland) and stored at −80°C under nitrogen head space until further analyses (no longer than 4 weeks).

The edible portion of each meal was 100 %. The sample size was one package, which was in most cases equivalent to one serving.

Five sub-samples per meal were taken for the non-Austrian and two for the Austrian meals. The sub-samples were selected from the same batch and analysed in duplicate.

Determination of the salt content

The chloride or sodium present in the meals is added as salt during food processing. Consequently, the salt content can be calculated stoichiometrically from the ready meals' chloride content, which was determined by a modified method of Mohr[38]. The method's reproducibility was verified by calculating relative standard deviation from measuring a control food sample (beef goulash with noodles) ten times on one day and alongside the regular samples' analyses. The mean value for salt was 1·18 g/100 g. The relative standard deviation from one day was 1·67 % and between days was 1·59 %.

Systemic survey of Austrian convenience foods

Data collection process

A total of 572 Austrian convenience foods from eight major food manufacturers (Knorr, Chef Menü, Iglo, Inzersdorfer, Wagner, Maggi, Spar Feine Küche and Dr. Oetker) and from one company providing organic products (Natur Compagnie) were included in the study. Data were collected at the supermarkets or from the companies' web pages or by personal contact with the companies. In-store data were recorded either by manual transcription into a record book or by photography of the item. All data were entered into a bespoke spreadsheet.

Product information collected

For each convenience food the brand name, product name, manufacturer, package size, number of portions per package, complete list of ingredients and the declaration of nutrients were collected. If only the sodium content was declared, salt was calculated by multiplying by 2·542.

Data presentation, comparison with recommended dietary salt intake levels and statistical analyses

All data were calculated per 100 g as well as per serving. From the collected data the number of products, the mean or median (depending on data distribution) and the range of salt contents were calculated in total, by meal category and by company.

The numbers of meals containing salt concentrations higher than the published targeted average salt intake level of 6 g/d[4–8] and the WHO recommendation of 5 g/d[3] for a main meal (= 30 % of the RDA) as well as for daily intake (100 %) were calculated.

The mean salt content of the ready meals originally available on the European market was compared with that from the newly developed ready meals with a Student's *t* test since all data were normally distributed. To determine whether there were differences between the Austrian convenience foods depending on the meal type category and the producing company, the data (not normally distributed) were analysed by performing both the Kruskal–Wallis *H* test and the Mann–Whitney *U* test with Bonferroni adjustment for multiple testing. Statistical differences were considered significant at $P < 0{\cdot}05$. All statistical analyses were performed using the statistical software package IBM SPSS Statistics version 20·0 for Microsoft Windows.

Results and discussion

The analysed salt concentrations of ready meals offered at European supermarkets and of the newly developed supposedly salt-reduced meals are shown in Table 1. The results of the comprehensive survey of Austrian convenience products overall and divided into the various meal type categories are shown in Table 2.

Ready meals available on the continental European market (n 32)

Salt contents in g/100 g

In total, the average salt content was 1·38 g/100 g. The salt contents of most meals ranged from 1 g/100 g to 2 g/100 g (Table 1). Salt content of < 1 g/100 g was found in salmon with pasta and vegetables; salmon with potatoes and sauce; chicken risotto with mango sauce; and chicken with carrots, peas and potatoes. The highest contents of > 2 g/100 g were found in roast pork with dumplings and Chinese chicken with rice. Significant differences in salt based on meal types (e.g. meat-based *v.* fish-based *v.* vegetarian) were not found.

Comparison of the salt contents (g/portion) with the targeted daily salt intake levels

The salt concentration per portion varied from 3·36 g to 7·72 g, with an average of 5·16 g/portion. Since all of the

Table 1 Salt content per 100 g edible portion and per serving of thirty-two European ready meals and of seven newly developed ready meals

Food name	*n*	Salt (g/100 g)			Portion size* (g)	Salt (g/portion)
		Mean	Min	Max		Mean
Currently available ready meals						
Chicken with rice and curry sauce	5	1·30	1·27	1·38	300	3·91
Chicken risotto with mango sauce	5	0·97	0·93	1·02	410	3·95
Chicken with carrots, peas, potatoes	5	0·74	0·71	0·77	500	3·72
Chicken risotto	5	1·52	1·47	1·57	310†	4·72
Chicken curry with rice	2	1·19	1·19	1·19	400	4·76
Asian rice dish with chicken	2	1·84	1·80	1·87	350	6·44
Chinese chicken with rice	2	2·06	2·00	2·11	330	6·78
Chicken with mushrooms and rice	2	1·02	1·01	1·02	330	3·36
Brun lapskaus	5	1·31	1·28	1·35	400†	5·25
Pork in spicy tomato sauce with rice	5	1·32	1·30	1·35	500	6·61
Roast pork with dumplings	2	2·03	1·99	2·07	380	7·72
Minced meat with mashed potatoes	2	1·43	1·36	1·50	330	4·72
Fillet of pork with rice	2	1·51	1·35	1·67	350	5·30
Pork with cabbage and potatoes	2	1·40	1·33	1·46	330	4·59
Kebab meat with rice and sauce	5	1·35	1·21	1·46	400	5·40
Beef stroganoff with rice	5	1·12	1·09	1·15	455	5·10
Beef goulash with spaetzle	2	1·48	1·47	1·48	400	5·90
Pasta with sauce Bolognese	2	1·07	0·99	1·15	350	3·74
Beef roulade with pasta	2	1·53	1·52	1·54	375	5·75
Venison ragout with dumplings	2	1·86	1·81	1·91	330	6·13
Aelpler Makkaronen	5	1·40	1·38	1·43	350	4·90
Mashed potatoes, kale and sausage	5	1·37	1·32	1·42	500	6·84
Lentil stew with dumplings	2	1·57	1·55	1·59	350	5·50
Filled dumplings with sauerkraut	2	1·53	1·52	1·54	350	5·37
Goulash with sausages and potatoes	2	1·53	1·52	1·53	350	5·34
Salmon with potatoes and sauce	5	0·85	0·83	0·88	490	4·18
Salmon with pasta and vegetables	5	0·71	0·67	0·74	500	3·54
Salmon with pasta and spinach	2	1·41	1·18	1·64	350	4·93
Catfish with ratatouille and rice	2	1·20	1·17	1·22	350	4·19
Pollack with rice	2	1·56	1·52	1·60	380	5·93
Pasta with spicy tomato sauce	2	1·47	1·40	1·54	330	4·85
Pasta with tomato-mozzarella sauce	2	1·46	1·45	1·46	400	5·82
Newly developed ready meals						
Chicken with rice and vegetables	5	0·78	0·74	0·81	470	3·65
Pork with mashed potatoes, carrots	5	1·21	1·15	1·27	360	4·34
Pork with mashed potatoes, broccoli	5	1·26	1·21	1·28	360	4·52
Lamb with sauce, rice and vegetables	5	0·64	0·61	0·70	470	3·00
Salmon with pasta and cauliflower	5	0·58	0·55	0·60	470	2·73
Salmon with potatoes and broccoli	5	0·56	0·54	0·58	440	2.47
Pasta with spinach–ricotta filling	5	1·27	1·24	1·32	380	4·83

*One serving is equivalent to the package size.
†The package sizes of two meals were larger than one serving and therefore their portion sizes were estimated.

ready meals analysed were designed to replace one complete main course (= 30 % of the RDA), their nutritional values were assessed by comparing the salt concentrations with both 30 % and 100 % of the targeted average daily salt intake for adults.

As shown in Table 3, all ready meals analysed exceeded 30 % of the targeted average daily salt intake, which depending on the reference is either 1·8 g[4–8] or 1·5 g[3]. More than 50 % of the meals exceeded the more restrictive targeted daily intake level of 5 g[3] and almost 20 % were above the more liberally set 6 g[4–8].

Comparison of our data with studies from the UK and Australia

As reported, high salt levels in all analysed continental European ready meals were found. In comparison with a survey of 265 Australian ready meals that showed a mean salt content of 0·70 g/100 g and a maximum value of 1·98 g/100 g[32], the average salt content analysed in the present study was higher, but the maximum levels were in the same range.

Back in 2003 ready meals with nearly 6 g salt per serving were also available on the British market[39]. However, four years later, after having implemented a national-wide governmentally led salt reduction campaign that combined consumer education, front-of-pack labelling and a voluntary food reformulation process[36], the average salt content of ready meals was successfully reduced to 0·49 g/100 g, with no meal containing more than 1 g/100 g. Regarding the portion size only 7 % of the meals exceeded 3 g salt/serving, which is half of an adult's maximum daily recommended intake[33].

Table 2 Salt content per 100 g edible portion and per serving of various Austrian convenience meals according to the package labelling (on 233 out of 572 collected packages, salt or sodium was labelled)

Meal type	*n*	Salt (g/100 g) Mean	Salt (g/100 g) Range	Portion size (g) Range	Salt (g/portion) Mean	Salt (g/portion) Range	Meals exceeding 30 % of recommendation: Most expert committees* No. of meals	% of meals	WHO† No. of meals	% of meals	Meals exceeding 100 % of recommendation: Most expert committees* No. of meals	% of meals	WHO† No. of meals	% of meals
All meals	233	1·07	0·23–7·37‡	135–500	3·18	0·46–15·89‡	200	86	216	93	26	11	48	21
Soups	50	1·02	0·51–1·53‡	150–330	2·54	1·53–5·03‡	47	94	50	100	0	0	1	2
Pasta dishes	48	1·27	0·51–4·83‡	145–500	3·98	1·68–14·42‡	45	93	48	100	13	27	16	33
Meat meals	42	1·02	0·25–3·31‡	135–370	3·48	0·84–9·23	37	88	40	95	1	2	6	14
Pizzas	31	1·55	1·20–1·98	250–400	5·15	3·43–7·34	31	100	31	100	7	23	16	52
Sweet meals	17	0·25	0·25–7·37‡	185–330	0·84	0·57–15·89‡	4	24	6	35	2	12	2	12
Cold meals	14	1·27	0·23–4·32	170–260	2·67	0·46–7·35	9	64	11	79	1	7	2	14
Salads	8	1·21	0·51–2·03	300–300	3·62	1·53–6·10	7	88	8	100	1	13	1	13
Savoury dumplings	7	1·49	1·27–1·78	200–350	3·90	2·54–6·23	7	100	7	100	1	14	3	43
Meals with potatoes, legumes or grains	7	1·11	0·51–1·53	330–350	3·80	1·68–5·34	6	86	7	100	0	0	1	14
Fish meals	6	0·89	0·51–1·02	330–360	3·05	1·68–3·66	5	83	6	100	0	0	0	0
Other meals	3	0·76	0·25–1·27	200–320	2·29	0·51–4·07	2	67	2	67	0	0	0	0

*Sources: Scientific Advisory Committee on Nutrition (2003); Deutsche Gesellschaft für Ernährung *et al.* (2000); Eurodiet (2000); Health Council of the Netherlands (2006); Nordic Council of Ministers (2004)[4–8].
†Source: WHO (2012)[3].
‡Median used because data were not normally distributed.

Thus, for ready meals in the UK combined governmental and food industrial efforts achieved a significant reduction of the meals' average salt contents from 2003 to 2007[33]. In contrast, average salt reduction in Australian ready meals failed[32]. The authors of the study identified as a major reason for the failure the lack of any coordinated salt reduction strategies from industry as a consequence of the missing governmental leadership. Until now there are still no salt reduction targets for ready meals set in Australia. Additionally, the programme is voluntary and there is no systemic and objective monitoring[32].

The results of our study indicate that the salt contents of all analysed continental European ready meals are too high. Therefore, the next step within the project was to develop new salt-reduced ready meals in cooperation with food-producing companies. The results of this food reformulation process are presented in the following section.

Nutrient composition of newly developed ready meals (n 7)

Establishing basic nutritional guidelines for the meal reformulation process

Easily understandable recommendations for the food producers to develop healthier meals with lower salt contents were established and together with other guidelines for improving the nutritional quality of ready meals, were published in various continental European trade journals, either in print or on the journals' web sites[40] to reach as many companies and retailers as possible. Regarding the salt content, the overall message was to use salt only in a limited amount and to improve taste with alternatives such as spices and herbs. We also emphasized the importance of a low amount of salt for the development of child-specific ready meals to avoid that children's taste adapts on salty.

Salt contents in g/100 g and in g/portion

The mean salt content of the newly developed meals was 0·90 g/100 g, ranging from 0·56 to 1·27 g/100 g. In comparison to the previously available ready meals that had been analysed, their salt levels were significantly lower (0·9 g/100 g *v.* 1·38 g/100 g; $P = 0.001$), which refers to an effective implementation of meal reformulation guidelines.

Taking the portion size into account, the salt content varied from 2·47 to 4·83 g/serving, with a mean of 3·65 g/serving. There were no meals exceeding previously mentioned targeted daily intake levels[3–8]. However, all newly developed ready meals yet exceeded the 30 % threshold of the recommendations for one main meal (Table 3).

Furthermore, the sensory attributes of two newly developed ready meals were tested in a consumer panel with 112 Norwegian adults (46 % males and 54 % females; 38 % 24–39 years of age, 42 % 40–55 years of age and 20 % 56–72 years of age). Despite their lower salt concentration

Table 3 Proportion of analysed ready meals exceeding 30 % and 100 % of targeted average salt intake per day

	Currently available ready meals		Newly developed ready meals	
	No. of meals	% of meals	No. of meals	% of meals
Meals exceeding 30 % of recommendations				
Most expert committees*	32	100	7	100
WHO†	32	100	7	100
Meals exceeding 100 % of recommendations				
Most expert committees*	6	19	0	0
WHO†	17	53	0	0

*Sources: Scientific Advisory Committee on Nutrition (2003); Deutsche Gesellschaft für Ernährung *et al.* (2000); Eurodiet (2000); Health Council of the Netherlands (2006); Nordic Council of Ministers (2004)[4–8].
†Source: WHO (2012)[3].

overall consumer acceptance including the flavour of both meals was rated very high (5·0 and 5·7, respectively, on a scale 1 = very dissatisfied and 7 = very satisfied)[41].

In summary, our results show that a stepwise salt reduction through the process of meal reformulation is necessary and achievable. Additionally, the data of the two sensory tested ready meals (chicken with rice and vegetables; salmon with pasta and cauliflower) suggest the possibility of salt reduction without compromising the sensory quality and shelf life of the products.

Comprehensive survey of Austrian convenience foods (n 572)

Nutrient declaration labels on 572 convenience foods from the Austrian market were collected. Sodium or salt contents were available for only 233 products (41 % of all). The overall average level of all convenience foods was 1·07 g salt/100 g or 3·18 g salt/portion (Table 2).

Differences in salt content by meal type category and meal-producing company

As is shown in Table 2 pizzas had the highest salt content, followed by pasta dishes and savoury dumplings. Pizzas and pasta dishes contained significantly more salt per serving than soups ($P < 0{\cdot}001$) and sweet meals ($P < 0{\cdot}001$). Furthermore the pizzas' salt contents were higher than those of meat meals ($P < 0{\cdot}001$), fish meals ($P < 0{\cdot}001$) and cold meals ($P < 0{\cdot}001$). Data from Australia and the UK collected from 2007 to 2009 report similar salt levels for pizzas[21,29,31] as were found within the present study. The lowest median salt content was found in sweet meals, followed by soups, 'other meals' and fish meals.

Variations of salt in apparently similar convenience meals

Interestingly, large variations were found not only between the different meal type categories, but also within meal groups (Table 2). Additionally, the salt contents of apparently similar ready meals produced by different companies were found to vary explicitly. For instance, a chilled pasta Bolognese showed a much lower salt content of 0·51 g/100 g as compared with another company's analogous meal having 1·27 g salt/100 g. This variation was also mirrored in other meal type categories. In the soups category, for instance, two competitive alphabet soups containing 1·02 and 1·53 g salt/100 g were found.

For pizzas some products that were advertised as fat reduced and supposedly healthier were found to be higher in salt (1·73 g/100 g) than the standard versions (1·53 g/100 g; 12 % less salt).

Although sweet meals on average had the lowest salt levels, a typical Austrian dish called Mohnnudeln (potato noodles with melted butter and poppy seeds) was one of the meals with the highest salt content of all (6·36 g/100 g). However, similar meals of competing companies showed a considerably lower salt content of 0·25 g/100 g (Mohnnudeln with apple sauce).

The discussed variations found in the present study were also observed in other studies from the UK and Australia[32,33].

Comparison of the salt contents in g/portion with the targeted daily salt intake levels

Our results show that the salt contents of approximately 90 % of all investigated Austrian convenience products exceeded 30 % of the recommended targeted daily salt intake levels[3–8] (Table 2). In seven out of eleven meal type categories (e.g. pizzas, pasta dishes or soups) all sampled meals contained more salt per portion relative to the targeted intake level of 1·5 g.

Twenty-one per cent of all meals, 52 % of pizzas, 33 % of pasta dishes and 14 % of meat meals had even higher salt concentrations than what is targeted by the WHO (5 g/d).

In summary, our results demonstrate that despite the above discussed large variations nearly all convenience products from the Austrian market are too high in salt.

Public health aspect

Our study proves that the salt contents of continental European ready meals and in particular those of Austrian convenience foods mostly exceed the targeted intake levels defined for one main meal (30 %) and some even the daily recommended dose (100 %). As the negative health effects of a high salt intake are well known and convenience foods play an important role in the daily diet, a salt reduction is crucial.

Most salt was found in pizzas and pasta dishes, the lowest concentrations in sweet meals. Large variations of the salt

levels (in total from 0·23 to 7·37 g/100 g) were found not only between and within the different meal type categories, but also between similar meals from different companies. In one case, for instance, a pasta dish contains 149 % more salt than the same meal from a competitive producer.

Furthermore, our data suggest that a stepwise reduction of the ready meals' salt content by meal reformulation is feasible without compromising the sensory quality. This is supported by successful salt reduction programmes implemented in the UK and Finland[33,35,36] and confirmed by a study on fast food[25]. That study's authors concluded that in the right regulatory context fast-food producers are probably able to reduce their products' salt contents considerably.

In Austria, however, there is no regulatory approach for reducing the salt content of convenience products in place. Moreover, a media campaign to raise consumer awareness regarding the negative impact of a high-salt diet on human health is missing and in 40 % of the meals declaration of the sodium and/or salt content is unavailable. This makes it difficult for consumers to choose between low- and high-salt options.

The current issue of high salt contents is comparable to the high levels of *trans*-fatty acids in convenience products and fast foods some years ago. Comprehensive investigations on the *trans*-fatty acid contents of various Austrian products confirmed that a harmful intake of *trans*-fatty acids was possible[42]. From there on, the government regulated the allowed amount of *trans*-fatty acids in foods by law[43]. This led to national-wide food reformulations by the food industry with the consequence that there are hardly any products with high *trans*-fatty acid levels on the market any longer.

Food reformulation is a 'key option to achieve population nutrition goals'[44] and so far some examples such as the Finnish salt reduction initiative have shown positive effects on human health. A key part of this initiative is the mandatory salt labelling which led to the disappearance of many highly salted foods from the market and a greater variety of salt-reduced products[45]. Thereby, the public health initiatives in Finland led to a significantly lower salt intake that is reflected by a decrease in the 24 h urinary sodium excretion during the last 20 years[46]. Besides, a reduction in the average blood pressure by more than 10 mmHg and a 75 % to 80 % decrease in mortality from both stroke and CHD could be observed[47]. These results are specifically important with regard to a different Finnish cohort study, which showed that a 100 mmol higher 24 h urinary sodium excretion led to a 51 % increased risk for CHD, a 45 % increased risk for CVD and a 26 % increased risk for all-cause mortality[48].

Asaria et *al.*[9] demonstrated that 8·5 million cardiovascular deaths in twenty-three countries could be averted by a 15 % mean population salt intake reduction over a period of 10 years. The costs for implementing an adequate salt reduction programme were estimated to be $US 0·09 per person per year.

Conclusion

A governmental-led strategy as is successfully established in the UK or Finland would be a good option to lower the salt content of Austrian and Central European convenience products including ready meals. Based on studies from the UK, Finland and Australia, it seems that legislation with either governmentally set salt reduction targets for various food groups or with mandatory labelling of the salt contents would be a more efficient way to successfully reduce the salt concentrations of foods than a voluntary-based programme without any monitoring.

Either way, an effective governmental-led salt reduction programme would result in a population-wide lower salt intake with a beneficial impact on blood pressure. Thus medical care costs and lives could be saved through the prevention of CVD.

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Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1368980014000731

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Trade journal publications I – III

Guidelines for the improvement of the nutritional quality of ready meals in Europe

Richtlinien für die Verbesserung der Nährstoffzusammensetzung von europäischen Fertiggerichten

S. Kanzler, K.-H. Wagner

Summary

In the last years the European market for ready meals has been steadily growing. More and more consumers are deciding in favour of the more convenient and time saving meals instead of traditional cooking. At the same time some recommendations for the nutrient and energy intake are not met. Therefore, one aim of the large European research project entitled "Double Fresh" is to evaluate the nutritional quality of existing ready meals by analysing the content of total energy, macronutrients, salt, some vitamins and the detailed fatty acid pattern. The results showed that the content of total energy of all meals is appropriate. But the contents of fat, in particular saturated fat, and of salt are too high and complex carbohydrates and dietary fibre are too low. Based on these key nutritional weaknesses general guidelines for all ready meal producers were established to improve the nutritional composition of their products.

Keywords:
ready meals, nutrient composition, energy, macronutrients, salt

Zusammenfassung

Der europäische Markt für Fertiggerichte ist in den letzten Jahren stetig gewachsen. Immer mehr Konsumenten greifen öfters zur bequemeren und Zeit sparenderen Variante des Kochens, den Fertiggerichten. Einige der Empfehlungen für die Energie- und Nährstoffzufuhr werden jedoch nicht erfüllt. Daher ist es ein Ziel des großen europäischen Projekts „Double Fresh", die Nährstoffzusammensetzung von derzeit angebotenen Fertiggerichten anhand der laborchemischen Analyse der Gehalte an Energie, Makronährstoffen, Salz, einiger Vitamine und des Fettsäuremusters zu erheben. Die Ergebnisse zeigten, dass der Energiegehalt der meisten Gerichte den Empfehlungen entspricht. Die Gehalte an (gesättigten) Fetten und Salz sind zu hoch, die an komplexen Kohlenhydraten und Ballaststoffen zu niedrig. Basierend auf diesen Daten wurden allgemein gültige Richtlinien zur Verbesserung der Nährstoffzusammensetzung von Fertiggerichten erstellt.

Kennwörter:
Fertiggerichte, Nährstoffzusammensetzung, Energie, Makronährstoffe, Salz

Introduction

Regarding the food consumption behaviour our society is changing. In the past, most foods were used at the initial grade without any industrial preparation (e.g. agricultural raw products such as vegetables, grain, potatoes). Today more and more foods are purchased with industrial prepreparation at different stages of convenience grades and fully prepared for consumption as so-called ready meals (ready-to-cook, ready-to-eat). Ready meals are supplied by retail stores or supermarkets or by home delivery services (home meal replacements), but they can also be consumed in canteens, gastronomy or places with catering or communal feeding [1, 2]. A survey from ACNielsen showed that in Europe 15% of the respondents purchase ready meals often, while another 39% purchase them at least sometimes. By far the main reason for buying ready meals is time scarcity, followed by the argument that buying all-in-one meals is cheaper than buying all ingredients for preparing a traditional meal from scratch [3]. The changes of society and working environment are the main reasons for the increasing demand and consumption of ready meals. The percentages of small households with singles, partnerships without children and single parents as well as elderly are rising [4, 5]. Regarding the economic environment there is a transition to flexible working hours, an increasing demand of multitasking [6] and a larger part of female employees [7]. Furthermore the technical equipment of today's kitchens with refrigerator, freezer and microwave oven is very advanced and the knowledge about preparing a traditional home-cooked meal is decreasing [8, 9, 10].
With this background the European project entitled "Double Fresh" aims on the one hand at the evaluation of the consumer expectations towards ready meals and on the other hand at the investigation of the quality of these products from different scientific aspects. Therefore various international universities, research institutes, companies and technological providers are working together to optimise the taste, the appearance, the nutritional quality, the microbiological safety and the shelf life. The working group in Vienna is focusing on analyzing, evaluating and optimising the nutritional quality in respect of the nutritional composition of the

currently offered ready meals. There is a great variety regarding the market of ready meals and until now there is no standardised definition for these products. One definition for convenience food which is widely used is the one given by Traub and Odland (1979). They defined convenience food as "any fully or partially prepared foods in which significant preparation time, culinary skills, or energy inputs have been transferred from the home kitchen to the food processor and distributor" [11]. This definition is applicable for the meals which are evaluated as part of the "Double Fresh" project, but they are all fully prepared foods supplied by manufacturers for in-house consumption and for replacing a complete meal (home meal replacements) [2]. Within the project we distinguish two different types of concepts. The first one, the so-called ready-to-cook meals, consists of a fresh meat or fish part, fresh vegetables, a precooked starch component (potato, rice or noodles) and a sauce in a microwaveable package with one or more separate chambers. The second one, the ready-to-eat meals, includes the same components as the meals above, but with a cooking step during production. This type of meals only needs to be reheated before consumption.

Materials and Methods

Within the study 16 European ready meals of eight different producers (Northern Europe, Benelux countries, Central Europe and Southern Europe) were analysed in detail at the Department of Nutritional Sciences, University of Vienna on the nutritionally most important parameters. Two of these meals were ready-to-cook and the other 14 were ready-to-eat meals. After preparing the meals according to the instructions given on the packages their content of total energy (bomb calorimeter), fat (extraction with ASE®100 after acidic pulping), carbohydrates (calculated by difference), protein (Kjeldahl), dietary fibre and sugars (both enzymatically), salt (titration) and some fat-soluble vitamins (HPLC with UV-VIS detection) as well as the detailed fatty acid pattern (GC-FID) as marker for the fat quality were measured. Based on the analytical assessment in the lab and in parallel with food databases (which are mainly used by the companies for their product labelling) key nutritional weaknesses were identified by comparing the data with the actual valid dietary allowances for the different European regions [12, 13, 14] and general guidelines for all ready meal producers were established in order to improve the quality of ready meals where necessary.

Results and Discussion

The energy content of most of the analysed meals is according to the dietary allowances for men and women of different age groups (adolescents, adults and elderly). Only a few meals contain more energy than recommended. The total fat contents of the various meals show large variations. The amount of protein exceeds the recommended level for almost all meals which is due to the content of meat or fish. Most of the meals contain less carbohydrates than recommended and only two out of the 16 meals reach the recommended amount of dietary fibres. Sugars (glucose, fructose and sucrose) are satisfying and much lower than recommended. All meals, as the main limitation, contain more salt than recommended for one portion, some meals even more than recommended for one day. According to the European Nutrition and Health Report 2004 the average protein intake of European adults was above the recommended level of 15% from total energy intake in some countries, whereas the mean carbohydrate intake was low. As a consequence of the low intake of carbohydrates the average intake of dietary fibre in European adults was low, too. On average, the fat intake and the estimated sodium intake in the participating countries was high [15]. These general findings regarding the nutrient intake of the European population are comparable with the nutrient composition of the analysed ready meals. Most of the meals also contained too much fat and sodium as part of salt and too less carbohydrates and dietary fibre.

Therefore, it could be stated that the content of total energy of almost all meals is appropriate but the content of fat and in particular saturated fat should be reduced. At the same time the content of complex carbohydrates and dietary fibre should be increased. For all meals a reduction of the salt content by at least 50% is needed. On basis of these results guidelines for an improvement of the nutritional quality were established. The simplest one without changing the recipe is to optimise the ratio of meat portion to side dishes such as noodles, rice and potatoes. More precisely, an increase of the side dishes would result in a higher amount of carbohydrates, whereas a smaller portion of meat (especially meat and sausage high in fat) would result in a lower content of fat and protein.

Furthermore it is important to increase the vegetable portion or if there are no vegetables at all to include them in the meal. It would be desirable to use different coloured vegetables, fruits or salads from different origin ("rainbow colours"), since they are in combination an optimal source for different micronutrients such as vitamins, carotenoids and other bioactive compounds. Another simple method to refer the consumer to a healthy food choice is the recommendation of salad as side dish or fruits as dessert with a short "health" notice on the package (in accordance with the national food law). Meals including sea fish or lake fish (also local fish) have a high nutritional value, since fish is rich in long chain n-3 unsaturated fatty acids, iodine, high-quality protein and it represents the main source of vitamin D.

The results show that the producers should be cautious with the amount and the kind of sauce which is added to the meal, because it is often based on fatty ingredients like mayonnaise or fatty milk products (e.g. cream).

To reduce the fat content of a sauce the fatty milk products can be replaced by skimmed milk powder. In order to increase the amount of dietary fibre the recipes should include more whole grain products (flour, pasta) and more brown or wild rice. This can be done either as starch component (pasta, rice) or as part of a sauce (flour). Since the fat quality of many products is improvable plant oils such as corn oil, sunflower oil, walnut oil, rapeseed oil, olive oil or also mixtures should be used. Plant oils are rich in unsaturated fatty acids, vitamin E and phytosterols. This leads at the same time to a reduction of animal fat which is rich in saturated fatty acids and cholesterol. The use of partially hydrogenated fats is critical and has to be avoided due to the content of transfatty acids. Most important is the reduction of salt. Salt is a common flavour additive but a high salt intake is associated with high blood pressure and increased risk for cardiovascular disease. Therefore the present salt content has to be reduced as far as possible. The use of spices and fresh or dried herbs to improve the taste of the meals is recommended.

Conclusion

For creating new health-optimised ready meals the following recommendations could be considered:

- The energy content of these meals should be according to the dietary allowances. In general, for male and female adults the content of energy for one meal should not be higher than approximately 700 kcal per serving.
- The focus should be on carbohydrate rich starch components as for example potatoes, noodles and rice (especially whole grain products).
- They should also include vegetables, salads or fruits in a higher amount.
- The portion of lean meat should be smaller in comparison to the side dishes and the meals should not include too much fatty sauce.
- The fats used should be predominantly from vegetable origin, animal fats should be reduced and partially hydrogenated fats avoided.
- The salt content should be low and the taste should be improved by using spices or herbs.

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Optimierung der Komponenten

Verbesserung der ernährungsphysiologischen Qualität von Fertiggerichten

Die Märkte für Fertiggerichte wachsen weltweit, und dieser Trend wird sich zukünftig weiter fortsetzen. Ein Grund dafür ist, dass immer mehr Konsumenten die einfacheren, bequemeren und Zeit sparenderen Fertiggerichte gegenüber dem herkömmlichen Kochen bevorzugen. Auf der anderen Seite werden in unseren Breiten einige der Empfehlungen für die Energie- und Nährstoffzufuhr nicht erfüllt. Daher ist ein Ziel des europäischen Projekts „Double Fresh", die Nährstoffzusammensetzung von derzeit am Markt erhältlichen Fertiggerichten mittels laborchemischen Analysen zu beurteilen und den Herstellern allgemein anwendbare Richtlinien zur diesbezüglichen Verbesserung ihrer Produkte zur Verfügung zu stellen.

Das Ernährungs- und Konsumverhalten der heutigen Gesellschaft unterliegt einem starken Wandel. In der Vergangenheit wurden die meisten Lebensmittel ohne jegliche industrielle Verarbeitung in Form von landwirtschaftlichen Rohprodukten wie zum Beispiel Gemüse, Getreide oder Kartoffeln gekauft (Grundstufe). Heutzutage werden immer mehr Lebensmittel mit industrieller Verarbeitung unterschiedlicher Convenience-Grade bis hin zu vollständig zubereiteten, verzehrfertigen Gerichten, den so genannten Fertiggerichten, bevorzugt. Letztere können entweder im Einzelhandel, im Supermarkt oder über Hauszustellung erstanden oder in Form der Außer-Haus-Verpflegung (Gastronomie, Gemeinschaftsverpflegung) konsumiert werden [1, 2]. Eine von AC Nielsen durchgeführte Studie zeigte, dass in Europa 15 Prozent der Befragten häufig zu Fertiggerichten greifen und weitere 39 Prozent diese gelegentlich konsumieren. Als Hauptgrund dafür wird Zeitmangel genannt, gefolgt von dem Argument, dass der Kauf von Komplettmahlzeiten billiger ist als die Beschaffung aller Einzelzutaten für die herkömmliche Zubereitung einer Mahlzeit [3].

Bestimmung des Proteingehalts nach Kjeldahl: Proben nach dem Säureaufschluss

Die Hauptgründe für die steigende Nachfrage und Verzehrshäufigkeit sowie das zunehmende Angebot liegen in den gesellschaftlichen Veränderungen der letzten Jahre. Die Anzahl von Kleinhaushalten mit Singles, kinderlosen Paaren und allein erziehenden Eltern sowie mit Älteren ist stark gestiegen [4, 5]. Die heutige Arbeitswelt ist gekennzeichnet durch die Forderung nach erhöhter Flexibilität bei der Arbeitszeit und nach Multitasking sowie durch eine steigende Anzahl an weiblichen Angestellten [6, 7]. Weiter ist die technische Ausstattung der modernen Küchen mit Kühlschrank, Tiefkühlschrank und Mikrowelle so gut wie nie zuvor, und die Kochkenntnisse der Bevölkerung haben stark abgenommen [8, 9, 10].

Wildlachsfilet mit Schnittlauchsauce und Reis nach dem Erhitzen in der Mikrowelle (bereits verzehrsfertig)

Vor diesem Hintergrund hat sich das europäische Projekt „Double Fresh" einerseits die Erhebung der Konsumentenerwartungen in Bezug auf Fertiggerichte und andererseits die Untersuchung und gegebenenfalls Optimierung der Qualität dieser Produkte auf unterschiedlichen Ebenen zum Ziel gesetzt. Daher arbeiten mehrere internationale Universitäten, Forschungseinrichtungen, Produzenten von Fertiggerichten und Technologieanbieter zusammen, um den Geschmack, das Aussehen, die ernährungsphysiologische Qualität, die mikrobiologische Sicherheit und die Haltbarkeit durch neue innovative Strategien zu verbessern. Die Aufgabe der Arbeitsgruppe in Wien/Österreich ist die Analyse, die Bewertung und die Optimierung der ernährungsphysiologischen Qualität in Bezug auf die Nährstoffzusammensetzung der derzeit am Markt angebotenen Fertiggerichte.

Der Markt von Fertiggerichten ist sehr vielfältig, und bis jetzt gibt es keine einheitliche Definition für diese Produkte. Häufig verwendet wird jene von Traub und Odland (1979), wobei unter Convenience-Produkten alle ganz oder teilweise verarbeiteten Lebensmittel verstanden werden, bei denen Zubereitungszeit, Kochkenntnisse oder Energieaufwand von der häuslichen Küche zum Lebensmittelhersteller und -händler transferiert wurden[11]. Diese Definition ist auch für jene Gerichte, die im Rahmen des Projekts „Double Fresh" untersucht wurden, anwendbar. Allerdings wurde der Fokus auf Produkte gelegt, die vollständig zubereitete Gerichte darstellen und von den Lebensmittelproduzenten für den Konsum zu Hause als Ersatz für eine komplette Mahlzeit angeboten werden. Innerhalb des Projekts wurden die Gerichte in zwei Kategorien unterteilt. Die erste Gruppe umfasst jene Gerichte, die aus einem frischen Stück Fleisch oder Fisch, einer frischen Gemüseportion, einer vorgekochten Stärkekomponente als Beilage (Kartoffeln, Reis oder Nudeln) und einer Sauce bestehen und in einer für die Mikrowelle geeigneten Verpackung mit einer oder mehr getrennten Kammern erhältlich sind (ready-to-cook). Die Gerichte der zweiten Gruppe beinhalten dieselben Komponenten wie die oben genannten Gerichte, werden aber während der Produktion erhitzt und müssen deshalb vor dem Verzehr nur noch erwärmt werden (ready-to-eat).

Material und Methoden

Im Rahmen der Studie wurden am Department für Ernährungswissenschaften der Universität Wien sechzehn europäische Fertiggerichte von acht ver-

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schiedenen Produzenten (Nordeuropa, Benelux, Mitteleuropa und Südeuropa) auf deren Nährstoffzusammensetzung analysiert. Zwei dieser Gerichte waren aus der Kategorie „ready-to-cook“, während die anderen vierzehn Gerichte in die Kategorie „ready-to-eat“ fielen. Nach der Zubereitung der Mahlzeiten entsprechend der Packungsangaben wurden die Gehalte an Energie (Kalorimeterbombe), Fett (Extraktion mit ASE 100 nach einem Säureaufschluss), Kohlenhydrate (berechnet), Protein (Kjeldahl), Ballaststoffe und Zucker (beides enzymatisch), Salz (Titration) und einige fettlösliche Vitamine (HPLC mit UV-Vis Detektion) sowie das Fettsäuremuster als Marker für die Fettqualität (GC-FID) gemessen. Parallel dazu wurde die Nährstoffzusammensetzung der Gerichte mithilfe von Lebensmitteldatenbanken berechnet, welche auch von den Produzenten für die Erstellung der Nährwertkennzeichnung verwendet werden. Ausgehend

Aschebestimmung: Rückstand nach Veraschung der Proben im Muffelofen

von den Laboranalysen und den durchgeführten Berechnungen wurden mittels Vergleich der Daten mit den derzeit gültigen Empfehlungen für die Nährstoffzufuhr verschiedener europäischer Regionen Problemnährstoffe identifiziert [12, 13, 14]. Basierend auf diesen Erkenntnissen wurden generelle Richtlinien für alle Produzenten von Fertiggerichten formuliert, um die Qualität der von ihnen angebotenen Gerichte gezielt zu verbessern.

Ergebnisse und Diskussion

Der Energiegehalt der analysierten Fertiggerichte entspricht im Allgemeinen den Empfehlungen für die Nährstoffzufuhr für Männer und Frauen verschiedener Altersgruppen (Jugendliche, Erwachsene und Ältere). Nur wenige Gerichte enthalten mehr Energie als empfohlen. Die Gesamtfettgehalte der unterschiedlichen Gerichte weisen große Streuungen auf. Der Proteingehalt fast aller Gerichte übersteigt die Empfehlungen, was auf den jeweiligen Fleisch- oder Fischgehalt der Gerichte zurückzuführen ist. Die meisten Gerichte enthalten weniger Kohlenhydrate als empfohlen und nur zwei der sechzehn Gerichte erreichen die empfohlene Menge an Ballaststoffen. Der Zuckergehalt (Glukose, Fruktose, Saccharose) aller Gerichte ist zufrieden stellend und liegt deutlich unterhalb der Empfehlungen. Alle Gerichte enthalten mehr Salz als für eine Portion empfohlen, einige Gerichte sogar mehr als für einen Tag empfohlen. Entsprechend der Daten des europäischen Ernährungsberichts 2004 lag die durchschnittliche Proteinaufnahme der europäischen Erwachsenen in manchen Ländern über der Empfehlung von max. 15 Prozent der Gesamtenergieaufnahme, wohingegen die mittlere Kohlenhydrataufnahme niedrig war. Als eine Folge der niedrigen Kohlenhydrataufnahme war die Ballaststoffaufnahme bei den europäischen Erwachsenen ebenfalls niedrig. Im Durchschnitt waren die Fettaufnahme und die geschätzte Natriumaufnahme der Erwachsenen der teilnehmenden Länder hoch [15]. Diese generellen Aussagen bezüglich der Nährstoffaufnahme der europäischen Bevölkerung sind vergleichbar mit der Nährstoffzusammensetzung der analysierten Fertiggerichte. So enthalten die meisten der untersuchten Gerichte ebenfalls zu viel Fett und Natrium als Bestandteil von Salz und zu wenig Kohlenhydrate und Ballaststoffe. Zusammengefasst ist der Gesamtenergiegehalt fast aller Gerichte entsprechend den Empfehlungen der Nährstoffzufuhr, aber die Gehalte an Fett und im Besonderen an gesättigten Fettsäuren sollten reduziert werden. Zur selben Zeit sollten die Gehalte an komplexen Kohlenhydraten und an Ballaststoffen erhöht werden. Für alle Gerichte ist eine Reduktion des Salzgehalts um wenigstens 50 Prozent wünschenswert.

Auf Basis dieser Ergebnisse wurden Richtlinien für die Verbesserung der ernährungsphysiologischen Qualität dieser Gerichte erstellt. Die einfachste Möglichkeit, ohne die Rezeptur zu verändern, ist eine Optimierung des Verhältnisses der Fleischportion zu den Beilagen (Nudeln, Reis und Kartoffeln), wobei eine Erhöhung der Beilagenmenge zu einem höheren Gehalt an Kohlenhydraten führt und eine kleinere Fleischportion, im Besonderem bei Fleisch und Wurst mit hohem Fettanteil, den Fett- und Proteingehalt verringert.

Weiter sollte die Gemüseportion vergrößert oder, falls das Gericht noch gar kein Gemüse enthält, eine in die Rezeptur inkludiert werden. Wünschenswert wäre die Verwendung von verschiedenfarbigem Gemüse, Früchten oder Salaten unterschiedlicher Herkunft („Regenbogen-Farben“), da diese in Kombination eine optimale Quelle für Mikronährstoffe wie Vitamine, Mineralstoffe, Carotinoide und andere sekundäre Pflanzeninhaltsstoffe sind. Eine andere Möglichkeit, um den Konsumenten auf eine gesündere Lebensmittelauswahl aufmerksam zu machen, ist die Empfehlung von Salat als Beilage oder Früchten als Dessert durch die Anbringung eines kurzen „Gesundheitshinweises“ auf der Verpackung (in Übereinstimmung mit dem nationalen Lebensmittelrecht).

Gerichte, welche Meeres- oder Süßwasserfische (auch heimische Arten) enthalten, haben einen hohen ernährungsphysiologischen Wert, da Fisch reich an langkettigen, ungesättigten Omega-3-Fettsäuren, Jod und hochwertigem Protein ist und die Hauptquelle für Vitamin D darstellt.

Die Ergebnisse zeigen, dass die Produzenten mit der Art und der Menge der Sauce, welche in den Gerichten enthalten ist, vorsichtig sein sollten, weil diese oft auf fetthaltigen Zutaten wie Mayonnaise oder fettreichen Milchprodukten wie Schlagobers oder Creme fraîche basiert. Um den Fettgehalt von Saucen zu reduzieren kann anstatt von fettreichen Milchprodukten Magermilchpulver verwendet werden.

Im Überblick

Lebensmittelrelevante EU-Forschungsprojekte

Neben „Double Fresh“ gibt es eine Vielzahl weiterer EU-finanzierter Projekte für den Lebensmittelbereich. Einen umfassenden Überblick erhält man über die Homepage CORDIS der Europäischen Kommission: http://cordis.europa.eu/search/index.cfm?fuseaction=proj.advSearch. Dazu bitte das Stichwort „food“ eingeben. Für eine gezieltere Suche empfiehlt es sich bei Framework Programme FP7-KBBE, FP6-Food und FP5-Life Quality anzuklicken. Dort sind alle Projekte aufgeführt, zu denen es eine lebensmittelthematische Ausschreibung gab. Aber auch über andere Programmakronyme sind interessante Projekte mit Lebensmittelbezug zu finden, z.B. unter FP7-Health, FP7-NMP, FP5-Human Potential oder FP5-Innovation SME. HJB/St.

Vegetarisches Fertiggericht in der Schale: Tortelloni mit Ricotta-/Spinatfüllung und Tomatensauce

Der Ballaststoffgehalt lässt sich durch den vermehrten Einsatz von Vollkorngetreideprodukten (Mehl, Pasta) und von Natur- oder Wildreis erhöhen. Dies kann entweder in Form der Stärkebeilage (Pasta, Reis) oder als Teil der Sauce (Mehl) umgesetzt werden.

Da die Fettqualität von vielen Fertiggerichten verbesserungswürdig ist, sollte in den Rezepturen pflanzlichen Ölen wie Maiskeimöl, Sonnenblumenöl, Walnussöl, Rapsöl, Olivenöl oder auch Mischungen daraus der Vorzug gegeben werden. Öle pflanzlichen Ursprungs sind reich an ungesättigten Fettsäuren, Vitamin E und an Phytosterolen. Durch die vermehrte Verwendung dieser Öle kommt es gleichzeitig zu einer Reduktion von tierischen Fetten, welche reich an gesättigten Fettsäuren und an Cholesterin sind. Die Verwendung von teilweise gehärteten Fetten ist problematisch und sollte wegen des Gehalts an Trans-Fettsäuren vermieden werden.

Von großer Bedeutung ist die Reduktion des Salzgehalts. Salz wird bei der Verarbeitung von Lebensmitteln häufig zur Verbesserung des Geschmacks verwendet, aber auch zur Verlängerung der Haltbarkeit. Eine hohe Salzaufnahme wird jedoch mit einem hohen Blutdruck und einem erhöhten Risiko für Herzkreislauferkrankungen assoziiert. Daher sollte der Salzgehalt so weit wie möglich reduziert werden. Empfohlen wird die Verwendung von Gewürzen und frischen oder getrockneten Kräutern, um den Geschmack der Gerichte zu verbessern.

Ausblick und Empfehlungen

Um neue, aus ernährungsphysiologischer Sicht optimierte Fertiggerichte zu kreieren, sollten die folgenden Strategien beachtet werden:

- Der Energiegehalt dieser Gerichte sollte den Empfehlungen für die Nährstoffzufuhr entsprechen. Generell sollte der Energiegehalt einer Mahlzeit für männliche und weibliche Erwachsene etwa 700 kcal pro Portion nicht überschreiten.
- Die Basis des Gerichts sollten kohlenhydratreiche Stärkekomponenten, wie zum Beispiel Kartoffeln, Nudeln oder Reis bilden. Dabei ist Vollkorngetreideprodukten der Vorzug zu geben.
- Die Gerichte sollten ebenfalls Gemüse, Salat oder Früchte in einer größeren Menge enthalten.
- Die Portion an magerem Fleisch sollte im Vergleich zu den Beilagen kleiner sein und das Gericht sollte nicht zu viel fettreiche Sauce enthalten.
- Die verwendeten Öle sollten vorwiegend pflanzlichen Ursprungs sein, tierische Fette sollten reduziert und teilweise gehärtete Fette sollten vermieden werden.
- Der Salzgehalt sollte niedrig sein und der Geschmack der Gerichte sollte durch die Verwendung von Gewürzen und Kräutern verbessert werden.

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ABBILDUNGEN: KANZLER

EU-FORSCHUNGSPROJEKT ERARBEITET EMPFEHLUNGEN FÜR PRODUZENTEN

Ernährungswissenschafter verbessern Fertiggerichte

Wiens Universität hat im Rahmen eines EU-Projekts Fertiggerichte unter die Lupe genommen und Empfehlungen für eine optimale Zusammensetzung ausgearbeitet.

So können sich die Wissenschaftler gute Mikrowellen-Gerichte wohl vorstellen: Mit viel Gemüse und gesundem Fisch.
Fotos: Archiv (Frenzel / Jütro)

Ein Ziel des europäischen Projekts „Double Fresh" ist die Beurteilung der Nährstoffzusammensetzung von derzeit am Markt erhältlichen Fertiggerichten. Durch laborchemische Analysen und die Erstellung von allgemein anwendbaren Richtlinien für Hersteller, soll eine entsprechende Verbesserung der Produkte erreicht werden.

An diesem Projekt arbeiten mehrere internationale Universitäten, Forschungseinrichtungen, Produzenten von Fertiggerichten und Technologieanbieter zusammen. Auch eine Arbeitsgruppe an der Universität Wien unter der Leitung von Univ.-Prof. Dr. Karl-Heinz Wagner, bei der auch Mag. Sonja Kanzler vom Department für Ernährungswissenschaften mitwirkt, ist an diesem wichtigen Projekt beteiligt. Sie untersuchten zwei Arten von Fertiggerichten. Die erste Gruppe umfasst Gerichte, die aus einem rohen Stück Fleisch oder Fisch, einer rohen Gemüseportion, einer vorgekochten Stärkekomponente als Beilage (Kartoffeln, Reis oder Nudeln) und einer Sauce bestehen und die in einer für die Mikrowelle geeigneten Verpackung mit einer oder mehr getrennten Kammern erhältlich sind (ready-to-cook). Die Gerichte der zweiten Gruppe beinhalten dieselben Komponenten wie die oben genannten Gerichte, werden aber während der Produktion erhitzt und müssen deshalb vor dem Verzehr nur noch erwärmt werden (ready-to-eat).

So wurde analysiert

Insgesamt wurden am Department für Ernährungswissenschaften der Universität Wien sechzehn europäische Fertiggerichte in fünf Chargen von acht verschiedenen Produzenten (Nordeuropa, Benelux, Mitteleuropa und Südeuropa) auf deren Nährstoffzusammensetzung hin analysiert. Zwei dieser Gerichte waren aus der Kategorie „ready-to-cook", während die anderen vierzehn Gerichte in die Kategorie „ready-to-eat" fielen. Nach der Zubereitung der Mahlzeiten entsprechend den Packungsangaben wurden die Gehalte an Energie, Fett, Kohlenhydraten, Protein, Ballaststoffen und Zucker, Salz und einigen fettlöslichen Vitaminen und das Fettsäuremuster gemessen. Parallel dazu wurde die Nährstoffzusammensetzung der Gerichte mit Hilfe von Lebensmitteldatenbanken, die auch von den Produzenten für die Erstellung der Nährwertkennzeichnung verwendet werden, berechnet.

Abschließend verglichen die Forscher die Daten mit den derzeit gültigen Empfehlungen für die Nährstoffzufuhr verschiedener europäischer Regionen, um Problemnährstoffe zu identifizieren. Aufbauend auf diesen Erkenntnissen wurden generelle Richtlinien für alle Produzenten von Fertiggerichten formuliert, um, so Dr. Wagner, „die Qualität der von ihnen angebotenen Gerichte gezielt zu verbessern".

Zuviel Protein und Salz, zuwenig Ballaststoffe

Beim Energiegehalt schnitten die analysierten Fertiggerichte gut ab. Er entsprach im Allgemeinen den Empfehlungen für die Nährstoffzufuhr für Männer und Frauen verschiedener Altersgruppen. Nur wenige Gerichte enthielten mehr Energie als empfohlen. Negativ fiel hingegen der Proteingehalt auf. Er überstieg bei fast allen Gerichten die Empfehlungen. „Die meisten Fertiggerichte", erklärt Dr. Wagner, „enthalten zudem weniger Kohlenhydrate als empfohlen und nur zwei der sechzehn Gerichte erreichen die empfohlene Menge an Ballaststoffen". Der Zuckergehalt aller Proben war zufrieden stellend und lag deutlich unterhalb der Empfehlungen. Alle Gerichte enthielten hingegen mehr Salz als für eine Portion empfohlen, einige Fertiggerichte überschritten sogar die für einen Tag empfohlene Menge!

Zusammengefasst bedeutet das: Die meisten der untersuchten Fertiggerichte enthalten zu viel Fett und Natrium als Bestandteil von Salz und zu wenig Kohlenhydrate und Ballaststoffe! Wagners Empfehlung an die Industrie daher: „Die Gehalte an Fett und im Besonderen an gesättigten Fettsäuren sollten reduziert werden. Zur selben Zeit sollten die Gehalte an komplexen Kohlenhydraten und an Ballaststoffen erhöht werden. Für alle Gerichte ist eine Reduktion des Salzgehalts um wenigstens 50 Prozent wünschenswert."

Neun Richtlinien für bessere Fertiggerichte

Auf Basis der Wiener Untersuchung erstellten Dr. Wagner und sein Team neun Richtlinien für die Verbesserung der ernährungsphysiologischen Qualität von Fertiggerichten.

Weniger Fleisch, mehr Beilagen

„Die einfachste Möglichkeit einer Verbesserung, ohne die Rezeptur zu verändern, ist eine Optimierung des Verhältnisses der Fleischportion zu den Beilagen wie Nudeln, Reis und Kartoffeln. Eine Erhöhung der Beilagenmenge führt zu einem höheren Gehalt an Kohlenhydraten und eine kleinere Fleischportion zu einem niedrigeren Gehalt an Proteinen. Die Portion an magerem Fleisch sollte im Vergleich zu den Beilagen kleiner sein."

Mehr Gemüse beigeben

„Die Gemüseportion soll vergrößert oder, falls das Gericht noch gar kein Gemüse enthält, dieses in die Rezeptur inkludiert werden. Wünschenswert wäre die Verwendung von verschiedenfarbigem Gemüse, Früchten oder Salaten unterschiedlicher Herkunft („Regenbogen-Farben"), da diese in Kombination eine optimale Quelle für Mikronährstoffe wie Vitamine, Mineralstoffe, Carotinoide und andere sekundäre Pflanzeninhaltsstoffe sind."

Salat und Früchte empfehlen

„Eine andere Möglichkeit um den Konsumenten auf eine gesündere Lebensmittelauswahl aufmerksam zu machen, ist die Empfehlung von Salat als Beilage oder Früchten als Dessert durch die Anbringung eines kurzen ´Gesundheitshinweises` auf der Verpackung (in Übereinstimmung mit dem nationalen Lebensmittelrecht)."

Gesunden Fisch einbauen

„Gerichte, welche Meeres- oder Süßwasserfische (auch heimische Arten) enthalten, haben einen hohen ernährungsphysiologischen Wert, da Fisch reich an langkettigen, ungesättigten Omega-3-Fettsäuren, Jod und hochwertigem Protein ist und die Hauptquelle für Vitamin D darstellt."

Universitäts-Professor Dr. Karl-Heinz Wagner und Mag. Sonja Kanzler nahmen Mikrowellen-Fertiggerichte unter die wissenschaftliche Lupe.

Sparsam mit Saucen umgehen

„Die Ergebnisse zeigen, dass die Produzenten mit der Art und der Menge der Sauce, welche in den Gerichten enthalten ist, vorsichtig sein sollten, weil diese oft auf fetthaltigen Zutaten wie Mayonnaise oder fettreichen Milchprodukten wie Schlagobers oder Crème fraîche basiert. Um den Fettgehalt von Saucen zu reduzieren, kann anstatt von fettreichen Milchprodukten Magermilchpulver verwendet werden."

Mehr Ballaststoffe zusetzen

„Der Ballaststoffgehalt lässt sich durch den vermehrten Einsatz von Vollkorngetreideprodukten (Mehl, Pasta) und von Natur- oder Wildreis erhöhen. Dies kann entweder in Form der Stärkebeilage (Pasta, Reis) oder als Teil der Sauce (Mehl) umgesetzt werden."

Auf die Qualität der Fette achten

„Da die Fettqualität von vielen Fertiggerichten verbesserungswürdig ist, sollte in den Rezepturen pflanzlichen Ölen wie Maiskeimöl, Sonnenblumenöl, Walnussöl, Rapsöl, Olivenöl oder auch Mischungen daraus der Vorzug gegeben werden. Öle pflanzlichen Ursprungs sind reich an ungesättigten Fettsäuren, Vitamin E und an Phytosterolen. Durch die vermehrte Verwendung dieser Öle kommt es gleichzeitig zu einer Reduktion von tierischen Fetten, welche reich an gesättigten Fettsäuren und an Cholesterin sind. Die Verwendung von teils gehärteten Fetten sollte wegen der Transfettsäuren vermieden werden."

Salzgehalt möglichst reduzieren

„Von großer Bedeutung ist die Reduktion des Salzgehalts. Empfohlen wird die Verwendung von Gewürzen und frischen oder getrockneten Kräutern, um den Geschmack der Gerichte zu verbessern."

Auf den Energiegehalt achten

„Der Energiegehalt dieser Gerichte sollte den Empfehlungen für die Nährstoffzufuhr entsprechen. Generell sollte der Energiegehalt einer Mahlzeit für männliche und weibliche Erwachsene etwa 700 kcal pro Portion nicht überschreiten." rs