

Energy Use for Cooking and Other Stages in the Life Cycle of Food

A study of wheat, spaghetti, pasta, barley, rice, potatoes,
couscous and mashed potatoes

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Abstract

In this study, electricity use for cooking wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes from potatoes mashed powder was measured. The measurements were made with cooking appliances and number of portions relevant for households. Hotplates, electric kettles and microwave ovens were used for measuring electricity use for cooking. We also estimated the energy use in the life cycle stages before cooking.

Energy use for cooking can be a large or dominating part in the energy use for some food products' life cycle. Such food products are of vegetable origin with low to medium degree of processing. Electricity use per portion for cooking varied between 0.11 MJ and 5.1 MJ and was greatly influenced by the choice of cooking appliance and the number of portions cooked. Cooking in a microwave oven with a sensor regulated simmering function was 36 % to 92 % more energy demanding compared to cooking on a hotplate. An electric kettle was 35 % to 60 % more energy efficient than a hotplate for boiling the water needed for cooking couscous and mashed potatoes from mashed potato powder. The electricity use for boiling water in an electric kettle was similar to the specific heat for water. A microwave oven was up to ten times more energy efficient than a conventional oven for baking potatoes. It was always more energy efficient to cook several portions at the same time. The differences were in the order of a factor two to three for wheat, barley, rice, potatoes, couscous and mashed potatoes. For spaghetti and fresh pasta the differences were smaller.

Electricity use for households' cooking matches' energy use for industrial food processing. There seem to be great possibilities for improving the energy efficiency of diets with respect to choice of ingredient and cooking method. Our study indicates that one portion of food commonly served as part of hot meals can be produced with life cycle energy inputs ranging from 0.33 MJ to 6.0 MJ per portion. Wheat and barley had the lowest energy inputs while fresh pasta, imported spaghetti and potatoes baked in a conventional oven had the highest energy inputs.

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1. Introduction

Accelerating climate change constitutes a threat to the ecosystems capacities for producing the ecological services necessary for sustaining human and other life (IPCC, 1998). Climate change is believed to be human induced through emissions of greenhouses gases such as carbon dioxide, methane and nitrous oxides (IPCC, 1996). Carbon dioxide, the main greenhouse gas, is emitted when fossil fuel is burned. Fossil fuels constitute the main energy source in developed countries where emissions per capita of carbon dioxide are highest. Searching for strategies to increase energy efficiency of products, services and consumption patterns in the developed countries thus has a high priority for curbing further climate change.

In developed countries, the food sector commonly amounts to 20 % of the total energy use. An estimate of the Swedish food sector showed that between 30-40 % of that energy is spent in and by households for cooking, storage and transportation (Uhlen, 1997). Increased energy efficiency for such operations thus seem necessary in the pursuit of more efficient consumption patterns.

This study focuses on electricity use for cooking in households and how such use can be minimised through choice of appliance, cooking method and number of portions cooked. We measured the electricity use for cooking wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes from powdered potatoes. We also estimated the energy use in the life cycle stages before cooking.

The food items were selected because their aggregated consumption is large in Sweden. The total consumption of potatoes, rice, spaghetti and mashed potato powder was 54 kg per person during 1999. This can be compared to the consumption of fresh and frozen meat during the same year which was 38 kg per person or the consumption of bread which was 38 kg per person (estimates from Swedish Board of Agriculture, 2000). Moreover, the selected products are consumed frequently, commonly twice per day when they may be part of a lunch and/or dinner. The selected food items can also be substituted for one another, although this is not always nutritionally acceptable (Kocktürk, 1998). From the study of Swedish food consumption patterns over time it is clear that the following change has taken place: while the consumption of potatoes has plummeted, the consumption of pasta and rice is on the increase (Carlsson-Kanyama, 1999). Couscous, whole wheat and barley are still marginal products on the Swedish market but with increasing interest for exotic or novel products their consumption may increase.

Estimates of energy use in the life cycle of foods have revealed that cooking can sometimes be a large contributor to the total (e.g. Olsson, 1998, Dutilh and Kramer, 2000). However, comprehensive data sets about energy use for different cooking methods, appliances and number of portions are incomplete or lacking (For an overview of data sources see Carlsson-Kanyama and Faist, 2000).

In summary the aim of the report is:

- To report levels of electricity use for cooking relevant for households.

- To find out to what extent electricity use for cooking is influenced by choice of cooking appliances. Examples of cooking appliances are hotplates, microwave ovens and electric kettles.
- To analyse the extent to which the number of portions can influence energy use.
- To investigate the importance of electricity use for cooking relative to other energy demanding stages in the life cycle.
- To discuss possibilities for more energy efficient diets based on our results.

The study was carried out as part of the research project “Urban Households and Consumption Related Resource Use” which is a joint undertaking by the Environmental Strategies Research Group and the Department of Home Economics, Gothenburg University. The main question in this project is to investigate to what extent households can make use of environmental information about food products for lowering resource use related to diets.

2. Materials and Methods

Wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes from potato powder were cooked ¹ in the laboratories of the Swedish Consumer Protection Agency, Stockholm. Electricity use, temperature and time were recorded simultaneously. ²

All food was cooked in portions for one person and four persons. Wheat, barley and rice were cooked on a hotplate of cast iron and in a microwave oven with a sensor regulated simmering function. ³ Spaghetti and pasta was cooked on a hotplate of cast iron. Potatoes were cooked on a hotplate of cast iron, in a microwave oven and in a conventional oven. Couscous and mashed potato powder only need boiling water for their cooking and the water was boiled on a hotplate of cast iron and in an electric kettle. Information about the amount of ingredients and the cooking time was taken from food the packages. Appendix A contains information about appliances, size of portions, uncertainties of measuring equipment and cooking time. All measurements were carried out twice.

An inventory of the life cycle energy use that occurs prior to cooking was carried out for all food items included in the study. The inventory was based on a data survey concerning energy use in the food sector (Carlsson-Kanyama and Faist, 2000) complemented with information from food producers. The functional unit was one portion of the selected food items. The system boundaries include farm production with production of farm inputs, drying of crops, processing, storage and transportation up to the retailer. The system boundaries exclude production of capital goods such as machinery and buildings. They also exclude packaging material, waste treatment, transportation from the retailer to the consumer and dishwashing. The economic value of products and by-products was the basis for allocation of energy use during processes with multiple outputs. The energy use was calculated as process energy with no inclusion of production and delivery energy, conversion and transmission losses.

¹ Cooking includes boiling and baking in this study.

² Only energy use is reported here. Records of temperature and time are kept at the Swedish Consumer Agency.

³ When using a microwave oven with a sensor regulated simmering function the simmering time can be programmed at the start of the cooking process.

3. Results

3.1 Electricity use for cooking

Electricity use for cooking the various food items is listed in Table 1 and Table 2.

Table 1: Electricity use for cooking wheat, spaghetti, pasta, barley, rice and potatoes on a hotplate, in a microwave oven or in a conventional oven. In MJ per portion, according to number of portions and appliance.

FOOD ITEM	APPLIANCE AND NUMBER OF PORTIONS				
	Hotplate, 1 portion	Hotplate, 4 portions	Microwave oven, 1 portion	Microwave oven, 4 portions	Conventional oven, 1 and 4 portions
Whole wheat, MJ/portion	0.29	0.11	0.45	0.15	–
Spaghetti, MJ/portion	0.85	0.54	–	–	–
Fresh pasta, MJ/portion	0.68	0.41	–	–	–
Barley, MJ/portion	0.47	0.18	0.76	0.27	–
Rice, MJ/portion	0.34	0.12	0.63	0.23	–
Potatoes, boiled, conventional method, MJ/portion ⁴	0.70	0.30 ⁵	–	–	–
Potatoes, boiled, energy saving method, MJ/portion ⁶	0.58	0.23	–	–	–
Baked potatoes, MJ/portion	–	–	0.54	0.51	5.1 and 1.3

Table 1 shows that the electricity use per portion varies from 0.11 MJ to 5.1 MJ. Generally, electricity use per portion was lowest when four portions were cooked. Under such circumstances, electricity use varied between 0.11 MJ to 1.3 MJ per portion, while cooking only one portion demanded between 0.29 MJ to 5.1 MJ per portion (Table 1). It was always more electricity demanding to cook whole wheat, rice and barley in a microwave oven with a sensor regulated simmering function compared to a hotplate. Cooking in such a microwave oven was between 36 % to 92 % more electricity demanding per portion for whole wheat, rice and barley. This is because electricity use per unit of time during simmering in the microwave oven greatly exceeds the energy use per unit of time when a hotplate is set for simmering. We

⁴ The potatoes were boiled until ready, simmering time approximately 25 minutes

⁵ Results from Kuik (1998).

⁶ The potatoes were simmered for 20 minutes, then the hotplate was turned off and the potatoes were left on it for another 10 minutes.

recorded four times higher electricity use per minute when simmering in the microwave oven compared to the hotplate kept at simmering. The high electricity demands for cooking spaghetti and fresh pasta is explained by the large amounts of water needed during cooking and the high temperatures needed for keeping the water boiling during the whole cooking process.

Table 1 shows that about the same amount of electricity was used for boiling a single portion of potatoes and baking a single portion of potatoes in a microwave oven. However, when one portion of potatoes was cooked together with three other portions the most electricity efficient option was to boil them on a hotplate using the energy saving method. Baking a single portion of potatoes in a conventional oven was 10 times more electricity demanding than baking them in a microwave oven. The conventional oven was by far the most electricity intensive way of cooking potatoes in our study.

Table 2: Electricity use for cooking mashed potatoes and couscous with the help of an electric kettle or a hotplate. In MJ per portion, according to number of portions and appliance

FOOD ITEM	APPLIANCE AND NUMBER OF PORTIONS			
	Electric kettle 1 portion	Electric kettle 4 portions	Hotplate 1 portion	Hotplate 4 portions
Potatoes mashed powder, MJ/portion	0.09	0.06	0.21	0.10
Cous-cous, MJ/portion	0.03	0.012	0.18	0.063

Considerable energy savings can be made if an electric kettle is used instead of a hotplate when mashed potatoes from mashed potato powder and couscous are cooked (Table 2). Six times more electricity was needed when a single portion of couscous was cooked using a hotplate instead of an electric kettle. A comparison between the electricity use for boiling water in an electric kettle or on a hotplate shows that it was between 35-60 % more efficient to use an electric kettle instead of a hotplate (Figure 1). An electric kettle can be used for boiling between 0.2 kg to 1 kg of water. The electricity use for boiling water in the electric kettle compares with the specific heat for water, which is 4.2 kJ per kg water and degree C. The specific heat for water is an estimate of the minimum energy needed for heating water.

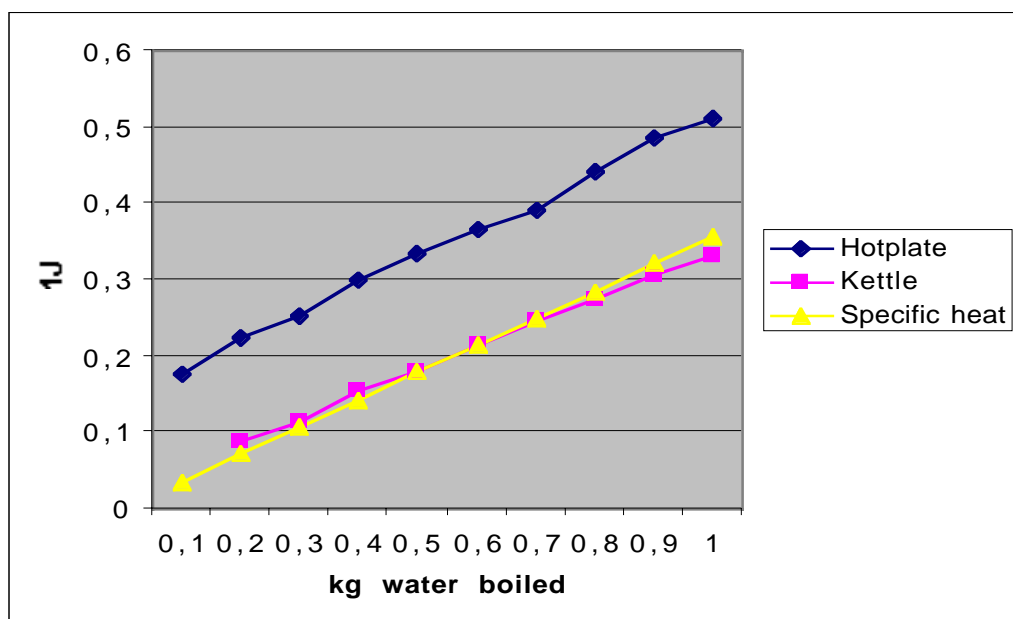


Figure 1: Electricity use for boiling water on a hotplate or in an electric kettle. In MJ according to appliance and amount of water boiled together with the specific heat for water.

3.2 Energy use during the life cycle of food items

3.2.1 Whole wheat

Whole wheat is commonly sold in packages of 0.5 kg in Sweden. Wheat grains are polished, steamed and dried to 14 % water content in order to obtain a product with a cooking time of 15 minutes. The main producer of whole wheat is located in Sweden and all wheat used by this producer is farmed in Sweden (Frebaco kvarn, pers.comm.). Long-term storage facilities are assumed to be located close to the production plant. Table 3 shows the mass flows for one portion of whole wheat. Mass flows are established in the early stages of a life cycle analysis and constitute the basis for calculation of resource use and emissions.

Table 3: Mass flows of one portion of whole wheat.

	KG	COMMENT
to stomach	0.120	One unit of dry wheat gives 2.7 units of cooked wheat (Mått för Mat, 2000)
to pot/oven	0.045	45 g per portion according to information on package
to household	0.046	Losses of 3 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to retailer	0.047	Losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.047	Losses at wholesaler not estimated
to storage facility	0.047	Losses during storage not estimated
to polishing and steaming	0.052	Losses during processing are 8%.
wheat cultivated	0.052	Losses during drying not estimated

The energy use during the life cycle of whole wheat is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 1.
- Long-term storage demands 0.025 MJ per kg during an assumed storage time of four months (Carlsson-Kanyama, 1998 in Carlsson-Kanyama and Faist, 2000). Storage at wholesalers and retailers demand 0.28 MJ per kg. This figure that includes seven days at a wholesaler with 0.013 MJ per kg, day and seven days at a retailer with 0.027 MJ per kg, day (Carlsson-Kanyama, 1998 in Carlsson-Kanyama and Faist, 2000).
- Energy use for polishing, steaming and drying amounts to 0.80 MJ per kg product produced. This figure was originally presented for oat flakes (Heiss, 1996 in Carlsson-Kanyama and Faist, 2000). A Swedish producer considers that the energy use for steaming whole wheat is equivalent to energy use for steaming oat flakes (Frebaco, pers.comm.). There is no market value of the losses during steaming of whole wheat (Frebaco kvarn, pers. comm.).
- Long-range transport is by truck, demanding 0.68 MJ per tonne-km and the distance between farm and wholesaler is 800 km. Distribution is carried out with truck that demands 2.5 MJ per tonne-km and the distance between wholesaler and retailer is 100 km.
- Drying demands 0.62 MJ per kg dried wheat. This figure includes electricity and oil use (Johansson, 1998 in 1996 in Carlsson-Kanyama and Faist, 2000).
- Farm production demands 1.9 MJ per kg wheat. This figure includes energy for production of farm inputs such as fertilisers and herbicides. Energy use for transport of farm inputs and fuel for farm operations are included (calculated from average data on inputs to wheat production presented in Carlsson-Kanyama and Faist, 2000).

Figure 2 shows the total energy use during the life cycle of whole wheat with four options for cooking included. Total energy use varies from 0.33 MJ per portion to 0.67 MJ per portion. Cooking is the most energy demanding stage for all options except example *a* where the portion was cooked on a hotplate together with three other portions. In this example, crop production dominates. The total energy use for example *d* is twice as high as for example *a*. It means that the influence during the consumption phase is of utmost importance for the life cycle energy used for whole wheat.

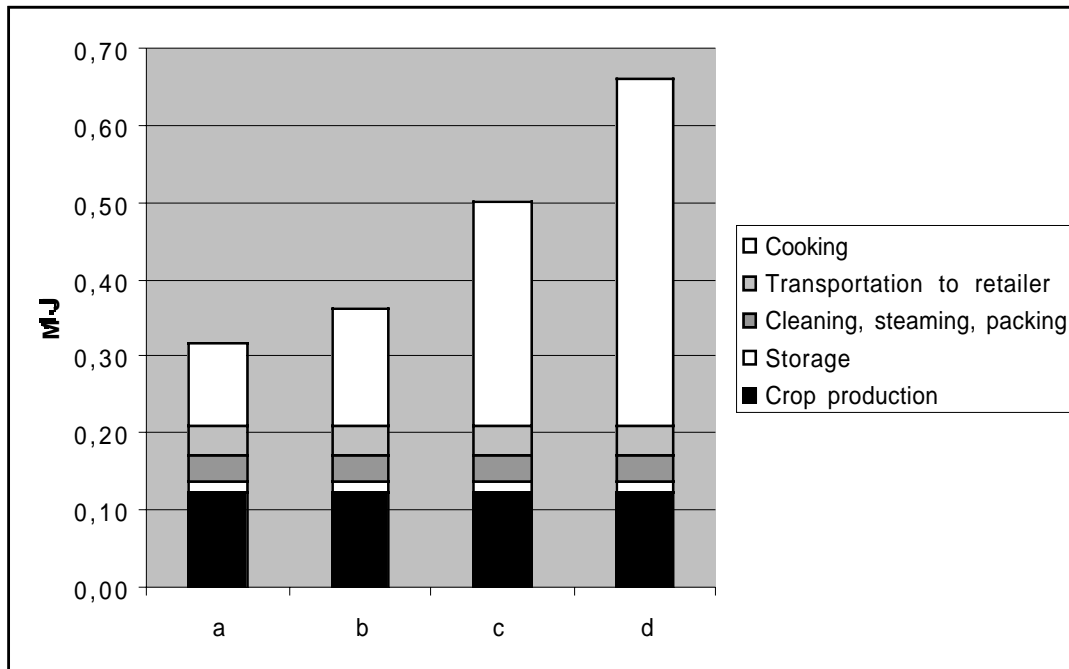


Figure 2: Energy use during the life cycle of one portion of whole wheat. In MJ per portion according to cooking mode. Example *a* was cooked on a hotplate as part of 4 portions, example *b* in a microwave oven as part of 4 portions, example *c* on a hotplate as a single portion and example *d* in a microwave oven as a single portion.

3.2.2 Spaghetti

Spaghetti is usually sold in packages of 0.5–1 kg in Sweden. The main components of spaghetti are wheat flour and water which is made into dough, formed and dried to 12 % water content. The cooking time is 7-8 minutes. A main producer of spaghetti is located in Sweden and wheat meal used at that plant is both of Swedish and southern European origin in the proportions of 60/40 (Cerealia AB, pers.comm.). Another main producer of spaghetti on the Swedish market is located in southern Italy. The wheat meal at that plant comes from Italy (Wasabröd, pers.comm.). Long-term storage facilities are assumed to be located close to the production plant. Table 4 shows the mass flows for one portion of spaghetti:

Table 4: Mass flows of one portion of spaghetti.

	KG	COMMENT
to stomach	0.18	one unit of dry spaghetti gives 2.5 units of cooked spaghetti (Mått för Mat, 2000)
to pot	0.070	70 g per portion according to information on package
to household	0.072	losses of 3 % (NFA, 1985 in Carlsson-Kanyama and Faist, 2000)
to retailer	0.074	losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.074	losses at wholesaler not estimated
to storage facility	0.074	losses during storage not estimated
to spaghetti plant	0.078	losses during processing are 4 % (Cerealia, pers. comm.)
to mill	0.098	80 % of the wheat to flour.
wheat cultivated	0.098	losses during drying not estimated

The energy use during the life cycle of spaghetti is calculated using the following assumptions and results:

- Energy use for cooking was taken from Table 1.
- Energy use per kg of product during storage is the same as in the example of whole wheat.
- Spaghetti fabrication demands 2.2 MJ per kg spaghetti including packing (Cerealia, pers.comm.). Allocation factor to meal is 94 % (Nordmills, pers.comm.).
- Milling demands 0.44 MJ per kg input (calculated from median energy use for milling presented in Carlsson-Kanyama and Faist, 2000).
- Long-range transport is carried with trucks, demanding 0.68 MJ per tonne-km and distribution with trucks demanding 2.5 MJ per tonne-km (NTM, 2000). For Swedish made pasta, the distance from farm to mill is 600 km, the distance from mill to factory 1540 km and the distance from factory to wholesaler 400 km. For Italian made pasta, the distance from farm to mill is 600 km, the distance from mill to factory 600 km and the distance from factory to wholesaler 3 500 km. The distance between wholesaler and retailer is 100 km.
- Energy use per kg of wheat during farm production and drying is the same as in the example of whole wheat.

Figure 3 shows the total energy use during the life cycle of spaghetti with two options for cooking and two options for spaghetti origin included. Total energy use varies from 1.2 MJ to 1.6 MJ per portion. Cooking is the most energy demanding stage for all options followed by crop production/transportation for Italian spaghetti. The option with the lowest energy use, Swedish made spaghetti cooked in four portions, is 26 % more energy efficient than option *d* which is one portion of spaghetti fabricated in Italy boiled in one portion.

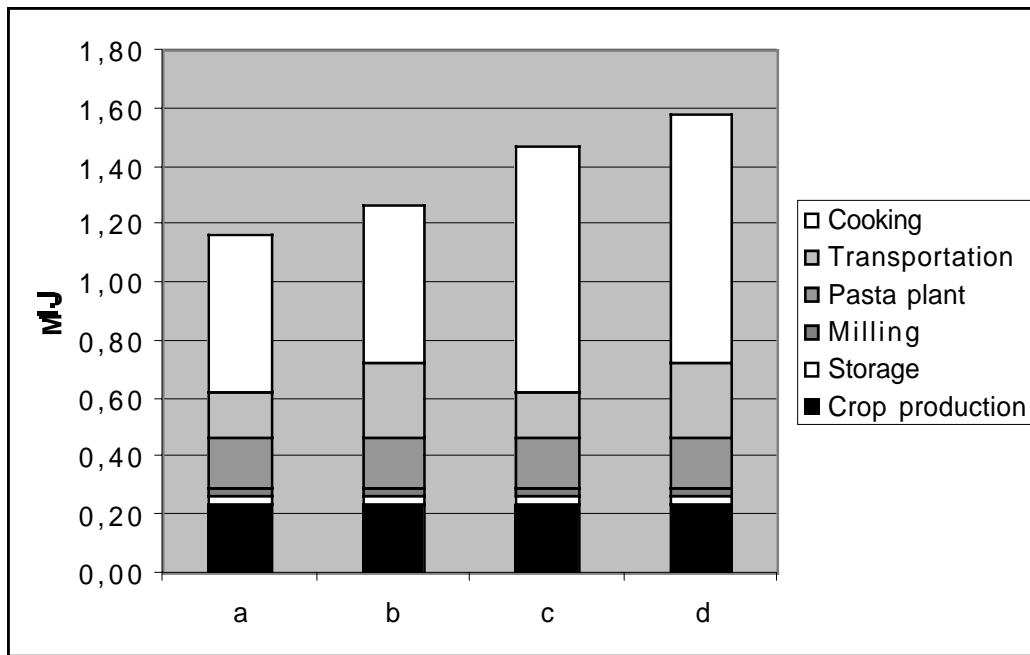


Figure 3: Energy use during the life cycle of one portion of spaghetti. In MJ per portion according to cooking mode and origin. Example *a* was made in Sweden and cooked on a hotplate as part of 4 portions, example *b* was made in Italy and cooked on a hotplate as part of 4 portions, example *c* was made in Sweden and cooked as a single portion and example *d* was made in Italy and cooked as a single portion.

3.3.3 Fresh pasta

Fresh pasta is commonly sold in packages of about 0.260 kg in Sweden. The main components of fresh pasta are wheat flour, eggs and water which is made into dough, formed and dried. The cooking time is 1 minute. Several producers of fresh pasta are located in Sweden and wheat meal used is often of southern European origin while the eggs come from Sweden. Fresh pasta must be stored at + 4 C° as opposed to spaghetti that can be stored at room temperature. Fresh pasta can be stored maximum six weeks and it is usually consumed three weeks after production (Cerealia AB, pers.comm.). Table 5 shows the mass flows for one portion of fresh pasta:

Table 5: Mass flows of one portion of fresh pasta

	KG	COMMENT
to stomach	0.22	one unit of fresh pasta gives 1.7 units of cooked pasta (Mått för Mat, 2000)
to pot	0.13	130 g per portion in the package
to household	0.13	losses of 3 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to retailer	0.13	losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000).)
to wholesaler	0.13	losses at wholesaler not estimated
to storage facility	0.13	losses during storage not estimated
to pasta plant	0.14	losses during processing are 4 % (Cerealia AB, pers. comm.)
to pasta plant, wheat flour	0.11	80% wheat flour in pasta (Cerealia AB, pers. comm.)
to pasta plant, egg slurry	0.03	20 % eggs in pasta (Cerealia AB, pers. comm.)
to mill, wheat flour	0.14	80 % of the wheat to flour.
wheat cultivated	0.14	losses during drying not estimated
to egg factory	0.032	losses due to removal of shells
feed consumed	0.078	2.4 kg of fodder per kg of eggs (SLU, 1996, in Carlsson-Kanyama and Faist, 2000)

The energy use during the life cycle of fresh pasta is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 1.
- Energy use per kg of product during storage of flour is the same as in the example of whole wheat. Energy use for storage of pasta requires 1.4 MJ per kg. The estimate includes 14 days at a wholesaler and seven days at a retailer. Energy use at the wholesaler is 0.019 MJ per kg, day and at the retailer 0.16 MJ per kg, day (Carlsson-Kanyama and Faist, 2000).
- Pasta fabrication requires 1.1 MJ per kg pasta including packing (Kungsörnen, pers.comm.).
- Long-range transport is by truck, demanding 0.68 MJ per tonne-km or by ship, 0.18 MJ per tonne-km. Distribution is carried out by truck demanding 2.5 MJ per tonne-km. For the transport of fresh pasta, refrigeration energy of about 10 % is added. For wheat, the distance from farm to mill is 600 km, the distance from mill to pasta factory 3 500 km and the distance from pasta factory to wholesaler 400 km. For eggs, the distance from farm to hen house is between 100 to 6000 km depending on fodder origin, the distance from hen house to the plant where the eggs are broken 400 km and the distance from egg slurry plant to pasta factory 200 km. The distance between wholesaler and retailer is 100 km.
- Energy use per kg of fodder crops vary from 1.7 MJ (barley) to 2.6 MJ (soy beans). Allocation to soy flour is 69% based on the economic value of flour and oil. Drying use the same amount of energy per kg as in the example of whole wheat. Fodder production

demands 0.32 MJ per kg output and the hen house uses 0.72 MJ per kg egg produced (Carlsson-Kanyama and Faist, 2000).

- Energy use per kg of wheat during farm production and drying is the same as in the example of whole wheat. Milling is estimated in the same way as for spaghetti.

Figure 4 shows the total energy use during the life cycle of fresh pasta with two options for cooking. Total energy use varies from 1.8 MJ to 2.1 MJ per portion. Cooking and production of wheat and eggs are the most energy demanding stages followed by transportation. The option with the lowest energy use, one portion boiled together with three other portions, is 13 % more energy efficient than when one portion is boiled alone.

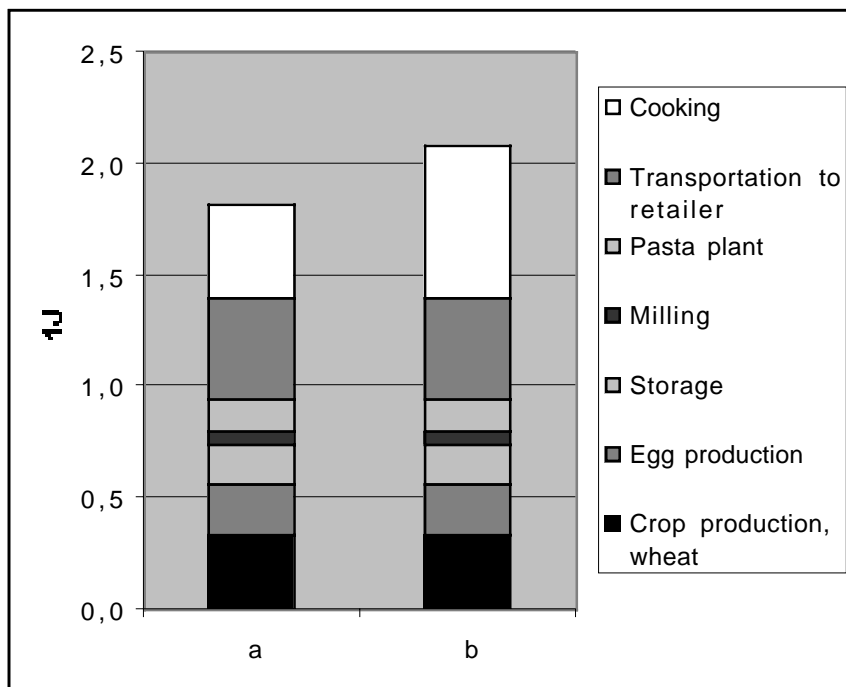


Figure 4: Energy use during the life cycle of one portion of fresh pasta. In MJ per portion according to cooking mode. Example *a* was cooked on a hotplate as part of 4 portions and example *b* was cooked on a hotplate as a single portion.

3.3.4 Barley

Barley is commonly sold in packages of 0.5 kg in Sweden. Barley grains are polished and cut in pieces in order to obtain a product with a cooking time of 30 minutes and water content of 10 %. The main producer of barley is located in Sweden and all barley used by this producer is farmed in Sweden (Cerealia AB, pers.comm.). Long-term storage facilities are assumed to be located close to the production plant. Table 6 shows the mass flows for one portion of barley:

Table 6: Mass flows of one portion of barley.

	KG	COMMENT
to stomach	0.19	one unit of dry barley gives 4.7 units of cooked barley (Mått för Mat, 2000)
to pot/oven	0.040	40 g per portion according to information on package
to household	0.041	losses of 3 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to retailer	0.042	losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.042	losses at wholesaler not estimated
to storage facility	0.042	losses during storage not estimated
to polishing and cutting	0.060	losses during processing are 30%.
barley cultivated	0.060	losses during drying not estimated

The energy use during the life cycle of barley is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 1.
- Energy use per kg of product during storage is the same as in the example of whole wheat.
- Energy use for polishing and cutting amounts to 0.13 MJ per kg product produced. This figure was originally presented for cleaning of peas (Carlsson-Kanyama, 1998 in Carlsson-Kanyama and Faist, 2000). A Swedish producer considers that the energy use for polishing and cutting barley may be equivalent to energy use for cleaning of peas (Cerealia AB, pers.comm.). The market value of barley for humans is 98% of the total during processing (Cerealia AB, pers. comm.).
- Long-range transport is carried by truck, demanding 0.68 MJ per tonne-km and the distance between farm and wholesaler totals is 800 km. ⁷ Distribution is by truck requires 2.5 MJ per tonne-km and the distance between wholesaler and retailer is 100 km.
- Drying demands 0.62 MJ per kg dried barley. This figure includes electricity and oil use (Johansson, 1998 in Carlsson-Kanyama and Faist, 2000).
- Farm production demands 1.7 MJ per kg barley. This figure includes energy for production of farm inputs such as fertilisers and herbicides. Energy use for transport of farm inputs and fuel for farm operations are included (calculated data on inputs to barley production from Swedish Environmental Protection Agency, 1997 in Carlsson-Kanyama and Faist, 2000).

Figure 5 shows the total energy use during the life cycle of barley with four options for cooking included. Total energy use varies from 0.37 MJ per portion to 0.95 MJ per portion.

⁷ Transportation distances from farm to processing plant may be overestimated according to a Swedish producer (Cerealia, pers.comm). At their plant, the distance from farm to plant is only 100 km.

Cooking is the most energy demanding stage for all options followed by crop farming. The total energy use for example *d* is 2.5 times higher than for example *a*. Again, the most efficient alternative is to boil one portion on a hotplate together with three other portions.

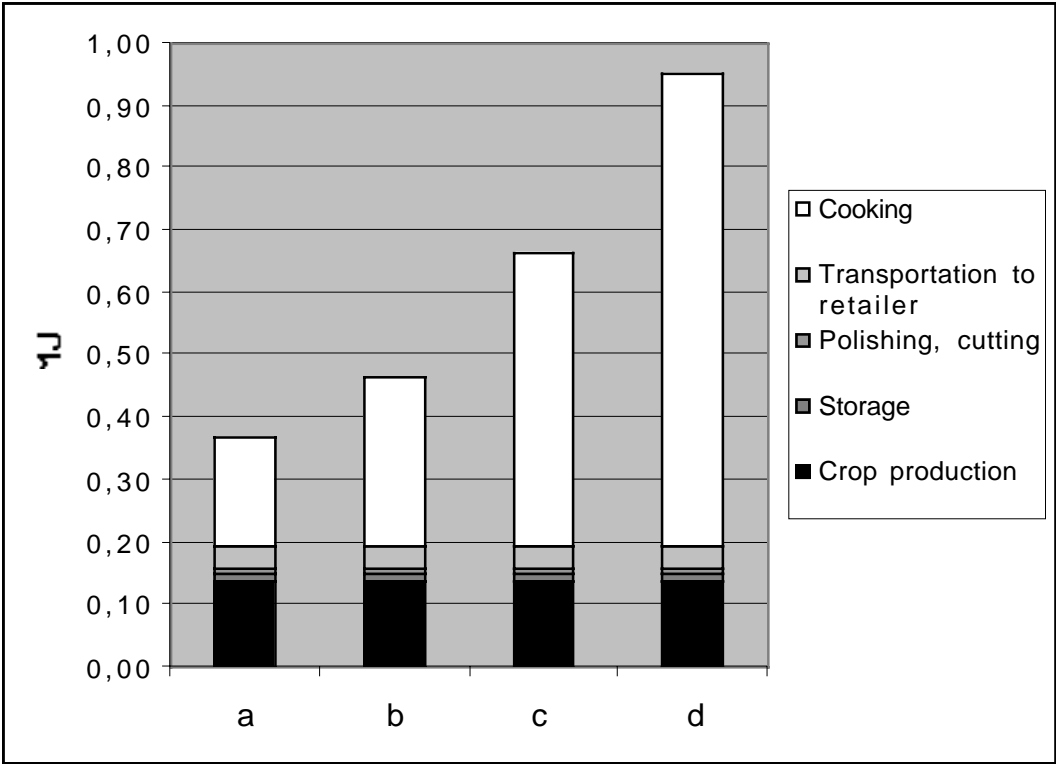


Figure 5: Energy use during the life cycle of one portion of barley. In MJ per portion according to cooking mode. Example *a* was cooked on a hotplate as part of 4 portions, example *b* in a microwave as part of 4 portions, example *c* on a hotplate as one portion and example *d* in a microwave alone as one portion.

3.3.5 Rice

Rice is commonly sold in packages of 0.5-25 kg in Sweden. The paddy is shelled to brown rice that is polished and packed. The cooking time varies from 10-20 minutes for polished rice with water a content of 12 %. Main rice producers are located in USA and South East Asia. Brown rice is usually imported to Europe due to lower taxes compared to polished rice. Par-boiling of paddy is a practise which was originally developed in order to prevent losses from insects attacks during storage. Par-boiled rice is becoming less common on the Swedish market due to today’s better storage and transportation techniques (Swedish Rice, pers.comm.). Long-term storage facilities are assumed to be located close to the production plant. Table 7 shows the mass flows for one portion of rice:

Table 7: Mass flows of one portion of rice.

	KG	COMMENT
to stomach	0.19	one unit of dry rice gives 3 units of cooked rice(Mått för Mat, 2000)
to pot/oven	0.060	60 g per portion according to information on package
to household	0.062	losses of 3 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to retailer	0.063	losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.063	losses at wholesaler not estimated
to storage facility	0.063	losses during storage not estimated
to polishing	0.090	losses during polishing are 20%.
to paddy plant	0.16	losses during paddy processing are 45 % (Swedish Rice, pers. comm.)
rice cultivated	0.16	losses during drying not estimated

The energy use during the life cycle of rice is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 1.
- Energy use per kg of product during storage is the same as in the example of whole wheat.
- Energy use for polishing amounts to 0.02 MJ per kg product produced (Carlsson-Kanyama and Faist, 2000). An equivalent amount of energy is used for paddy processing. The market value of rice is 93% of the total output during polishing. There is no value of the losses during paddy processing (Swedish Rice, pers. comm.).
- Long-range transport is by truck, demanding 0.68 MJ per tonne-km or by ship using 0.18 MJ per tonne-km. Distribution is by truck requiring 2.5 MJ per tonne-km. The distance from farm to paddy factory is 300 km, from paddy factory to harbour 750 km, from harbour to polisher 12 000 km, from polisher to wholesaler 1 500 km and from wholesaler to retailer 100 km.
- Drying of rice demands 0.62 MJ per kg dried rice. This figure includes electricity and oil use (Johansson, 1998 in Carlsson-Kanyama and Faist, 2000).
- Farm production demands 3.5 MJ per kg rice. This figure includes energy for production of farm inputs such as fertilisers and herbicides. Energy use for transport of farm inputs and fuel for farm operations with irrigation are included (average data for rice cultivation in Carlsson-Kanyama and Faist, 2000).

Figure 6 shows the total energy use during the life cycle of rice with four options for cooking included. Total energy use varies from 1 MJ per portion to 1.5 MJ per portion. Crop farming is the most energy demanding stage for most options followed by transportation/cooking. The total energy use for example *a* is 30 % lower than for example *d*.

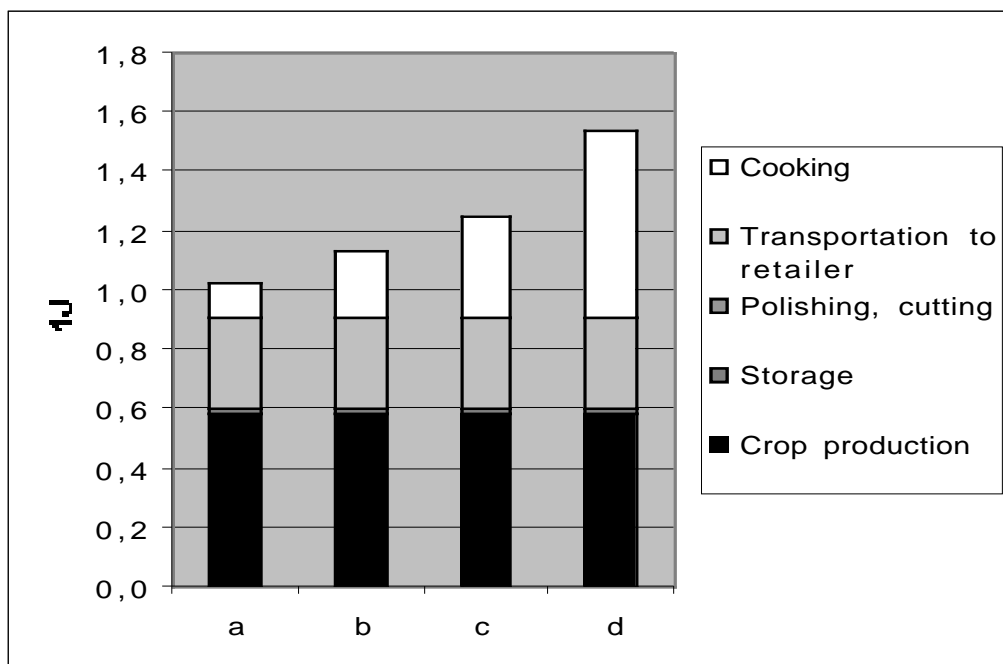


Figure 6: Energy use during the life cycle of one portion of rice. In MJ per portion according to cooking mode. Example *a* was cooked on a hotplate as part of 4 portions, , example *b* in a microwave oven as part of 4 portions, example *c* on a hotplate as a single portion and example *d* in a microwave as a single portion.

3.3.6 Potatoes

Potatoes are commonly sold in packages of 2–5 kg in Sweden or by loose weight. Potatoes are sorted, stored and packed with no further processing. The water content of potatoes is 80 %. The cooking time is about 30 minutes when potatoes are boiled, 7–24 minutes when they are baked in a microwave oven and 65 minutes when they are baked in a conventional oven. Most potatoes eaten in Sweden are farmed within the country. Long-term storage facilities are assumed to be located close to the farm. The potato examples covers boiled potatoes and baked potatoes. Table 8 shows the mass flows for one portion of boiled potatoes:⁸

Table 8: Mass flows of one portion of boiled potatoes.

	KG	COMMENT
to stomach	0.20	negligible weight loss during cooking (Mått för Mat, 2000)
to pot/oven	0.20	200 g per portion when boiled (Mått för Mat, 2000).
to household	0.24	losses of 16 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to retailer	0.28	losses of 16 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.28	losses at wholesaler not estimated
to storage facility	0.35	losses during storage are 18 % (Carlsson-Kanyama, 1998)
potatoes cultivated	0.35	

⁸ The potatoes were boiled with peels and they can be consumed that way. If they are peeled after boiling the weight loss is 10 % (Mått för Mat, 2000).

The energy use during the life cycle of boiled potatoes is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 1.
- Energy use per kg of potato for storage was calculated in the same manner as for whole wheat.
- Energy use for packing and sorting amounts to 0.21 MJ per kg product. (Stadig, 1997, figure presented for apples in Carlsson-Kanyama and Faist, 2000).
- Long-range transports is by truck, demanding 0.68 MJ per tonne-km while Distribution is by truck requiring 2.5 MJ per tonne-km. The distance from farm to storage/packing is 200 km, from storage to wholesaler 600 km and from wholesaler to retailer 100 km
- Farm production demands 0.67 MJ per kg potato. This figure includes energy for production of farm inputs such as fertilisers and herbicides. Energy use for transport of farm inputs and fuel for farm operations are included (average data for potato cultivation in Carlsson-Kanyama and Faist, 2000).

Figure 7 shows the total energy use during the life cycle of boiled potatoes with four options for cooking included. Total energy use varies from 0.85 MJ per portion to 1.3 MJ per portion. Cooking is the most energy demanding stage for most options followed by crop farming. The total energy use for example *a* is 36 % lower than for example *d*.

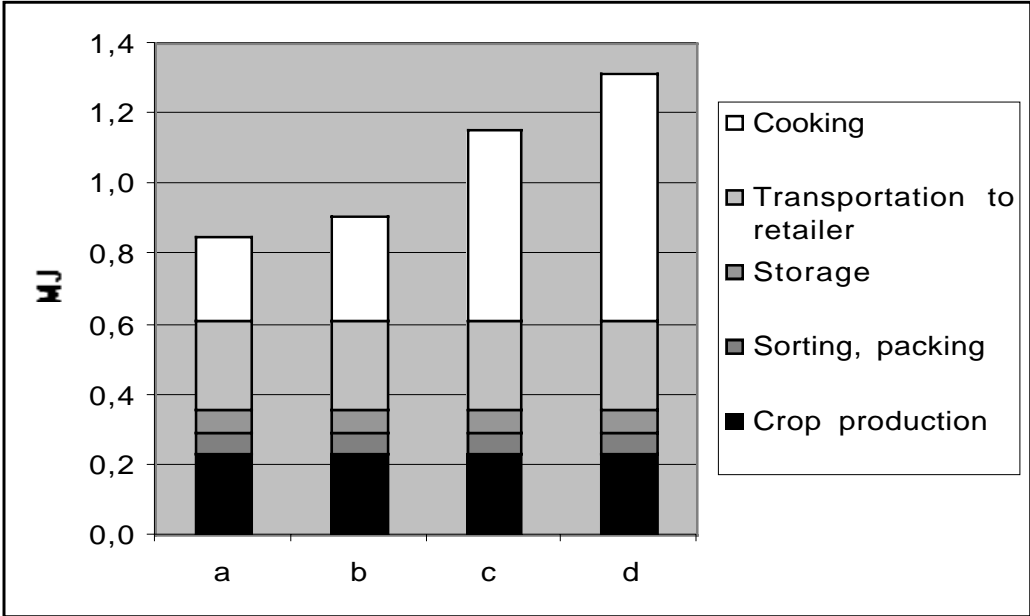


Figure 7: Energy use during the life cycle of one portion of boiled potatoes. In MJ per portion according to cooking mode. Example *a* was cooked on a hotplate as part of 4 portions and an energy saving method, example *b* on a hotplate as part of 4 portions and a conventional method, example *c* on a hotplate as a single portion and an energy saving method and example *d* on a hotplate as a single portion and a conventional method.

The mass flows for one portion of baked potatoes are similar to the ones presented for boiled potatoes except that one portion of potatoes weighs 300 g (Mått för Mat, 2000). Figure 8 shows the energy use for potatoes baked in a microwave oven and in a conventional oven. The energy use varies from 1.43 to 6.0 MJ per portion. Choosing the microwave oven instead of the conventional oven for baking a single portion of potatoes reduces the energy use by a factor four.

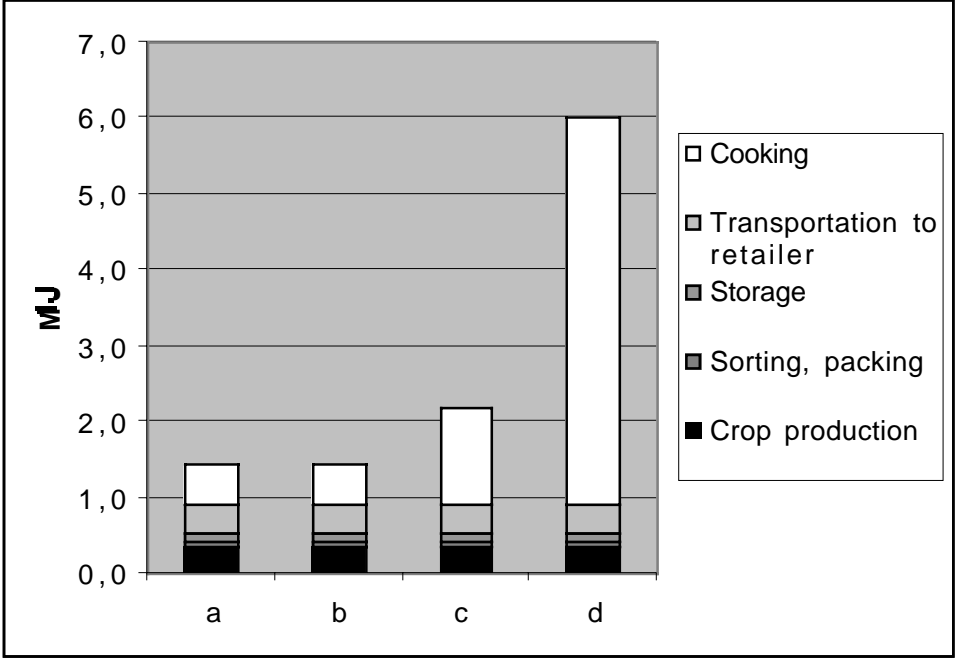


Figure 8: Energy use during the life cycle of one portion of baked potatoes. In MJ per portion according to cooking mode. Example *a* was cooked in a microwave oven as part of 4 portions, example *b* in a microwave oven as a single portion, example *c* in a conventional oven as part of 4 portions and example *d* in a conventional oven as a single portion.

3.3.7 Couscous

Couscous is commonly sold in packages of 0.5 kg in Sweden. Durum wheat semolina is moistened, then rolled to obtain small grains that are steam cooked, dried and calibrated. Couscous has 12 % water content. The cooking consists of mixing the couscous with boiling water. Couscous sold in Sweden is always imported from several countries, including France. Table 9 shows the mass flows for one portion of couscous:

Table 9: Mass flows of one portion of couscous.

	KG	COMMENT
to stomach	0.21	one unit of dry couscous gives 2.06 units of cooked couscous (Mått för Mat, 2000)
to pot	0.10	100 g per portion according to information on package
to household	0.10	losses of 3 % (NFA, 1985 in Carlsson-Kanyama and Faist, 2000)
to retailer	0.11	losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.11	losses at wholesaler not estimated
to storage facility	0.11	losses during storage not estimated
to couscous plant	0.11	losses during processing are 2-3 % (Frebaco, pers. comm.)
to mill	0.14	no information on semolina production. Assumption as for milling with 80 % of the wheat to meal.
wheat cultivated	0.14	losses during drying not estimated

The energy use during the life cycle of couscous is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 2.
- Energy use per kg of product during storage is the same as in the example of whole wheat.
- Couscous fabrication demands 2.7 MJ per kg couscous (Frebaco, pers.comm.)
- Energy use for milling and allocation procedures are the same as in the example for spaghetti.
- Long-range transports is by truck, demanding 0.68 MJ per tonne-km and distribution is by truck requiring 2.5 MJ per tonne-km. The distance from farm to mill is 600 km, the distance from mill to factory 600 km and the distance from factory to wholesaler 2000 km. The distance between wholesaler and retailer is 100 km.
- Energy use per kg of wheat during farm production and drying is the same as in the example of whole wheat.

Figure 9 shows the total energy use during the life cycle of couscous with four options for cooking included. Total energy use varies from 0.98 MJ per portion to 1.1 MJ per portion. Cooking is not the most energy demanding stage, in any of the options, in the life cycle dominated by crop production/transportation/processing. The option with the lowest energy use, a portion cooked as part of 4 portions, and an electric kettle, is 13 % more energy efficient than a portion cooked as a single portion using a hotplate.

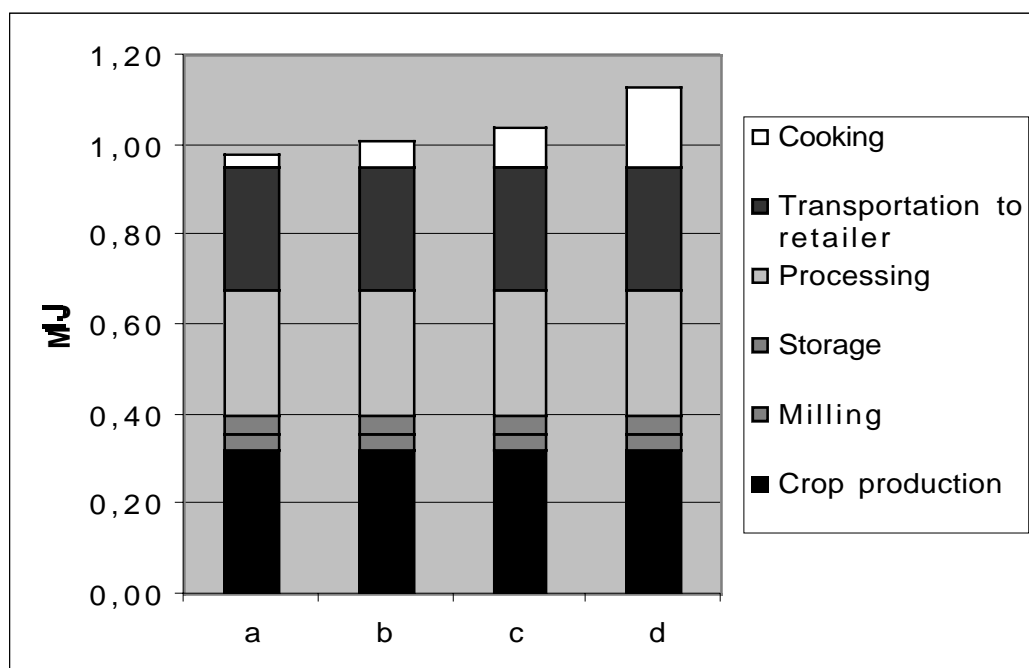


Figure 9: Energy use during the life cycle of one portion of couscous. In MJ per portion according to cooking mode. Example *a* was cooked with an electric kettle as part of 4 portions, example *b* as a single portion with an electric kettle, example *c* on a hotplate as part of 4 portions and example *d* on a hotplate as a single portion.

3.3.8 Mashed potatoes from mashed potato powder

Mashed potato powder is commonly sold in packages of 0.5-2 kg in Sweden. Potatoes are sorted, stored and processed into potato flakes that has a water content of 7 %. Mashed potato powder contains small amounts of milk and fat, not considered here. The cooking consists of mixing the powder with boiling water. Most mashed potato powder consumed in Sweden is produced within the country from potatoes grown in Sweden. Table 10 shows the mass flows for one portion of mashed potatoes made from mashed potato powder:

Table 10: Mass flows of one portion of mashed potatoes from mashed potato powder

	KG	COMMENT
to stomach	0.20	one unit of mashed potato powder give 5.7 units of mashed potatoes (Mått för Mat, 2000)
to cooking	0.035	35g per portion according to information on the package
to household	0.036	losses of 3 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to retailer	0.037	losses of 2 % (NFA, 1985, in Carlsson-Kanyama and Faist, 2000)
to wholesaler	0.037	losses at wholesaler not estimated
to processing	0.20	5.3 kg of potatoes are needed for each kg of mashed potato powder (information on food package).
to storage facility	0.24	losses during storage are 18 % (Carlsson-Kanyama, 1998)
potatoes cultivated	0.24	

The energy use during the life cycle of mashed potatoes from mashed potato powder is calculated using the following assumptions and results:

- Energy use for cooking (cooking) was taken from Table 2.
- Energy use for packing, sorting and storage is calculated in the same manner as for fresh potatoes.
- Processing demands 18 MJ per kg of output (Procordia Foods, 1998, pers. comm. in Carlsson-Kanyama and Faist, 2000).
- Long-range transports is by truck demanding 0.68 MJ per tonne-km while distribution is by truck requiring 2.5 MJ per tonne-km. The distance from farm to storage/packing is 200 km, from storage to processing 200 km, from processing to wholesaler 400 km and from wholesaler to retailer 100 km.
- Energy use for farm production was calculated in the same way as for potatoes.

Figure 10 shows the total energy use during the life cycle of mashed potatoes with four options for cooking included. Total energy use varies from 1.0 MJ per portion to 1.2 MJ per portion. Food processing is the most energy demanding stage for all options followed by crop farming. The total energy use for example *a* is 13 % lower than for example *d*.



Figure 10: Energy use during the life cycle of one portion of mashed potatoes from mashed potato powder. In MJ per portion according to cooking mode. Example *a* was cooked with an electric kettle as part of 4 portions, example *b* as a single portion with an electric kettle, example *c* on a hotplate as part of 4 portions and example *d* on a hotplate as a single portion.

4. Discussion

4.1 Uncertainties

There are a number of uncertainties related to the assumptions made in this study. They need to be discussed as they are of importance for the credibility of the results.

Deviations from the levels of electricity use reported for cooking (presented in Tables 1 and 2) were less than 10 % in our measurements. The reported levels are relevant for similar appliances and types of pots as the ones we used in our trials (see further Appendix A). Previous research carried out at the Swedish Consumer Agency has showed that the energy efficiency of pots strongly influences energy use during cooking. Energy inefficient pots may increase energy use by 30 %. A dirty hotplate also increases energy use. In our trials we used clean hotplates and energy efficient pots. If a cooking zone on a glass ceramic hob is used, electricity use may decrease by 20 % compared to a solid hotplate.

Energy use for cooking depends, among others, on the amount of water used. The amount of water needed for cooking in this study was taken from the recipes on food packages. Other recipes may recommend smaller or larger amounts of water. If less water is used, less energy is needed. Effects from such changes on food quality remains to be investigated.

Energy use for food processing was a major contributor to the total for several food items in this study. For mashed potato powder, processing contributed to 57-66 % of the total. The assumed energy use was 18 MJ per kg of output. A Swedish producer with a large modern plant provided us with that figure. Other studies report a much higher energy use, from 25 to 42 MJ per kg output for processing of mashed potato powder (Carlsson-Kanyama and Faist, 2000). If twice as much energy was used during processing of mashed potato powder as in our study, total life cycle energy use for one portion of mashed potatoes will vary from 1.6 MJ to 1.8 MJ instead of the previously calculated 1.0 MJ to 1.2 MJ per portion.

The assumption that 0.8 MJ per kg of output was used for steaming whole wheat is also a source of uncertainty. The figure was originally presented for oat flakes (Heiss, 1986, in Carlsson-Kanyama and Faist, 2000) and then used for whole wheat as the processes are similar (Frebaco Kvarn, pers.comm). An estimate from a Swedish producer of oat flakes indicated that energy use for processing can be 3-4 times higher than our assumption (Cerealia, pers.comm.). If we assume that the energy use for steaming whole wheat is four times higher, total energy use per portion of whole wheat will vary from 0.44 MJ to 0.78 MJ instead of the previously calculated 0.33 MJ to 0.67 MJ per portion.

The calculations of energy use for crop farming are based on data from several studies and averages have been used whenever possible. The main uncertainties in our study probably do not emanate from estimations of energy use in crop farming. We have the same opinion about transportation, although assumptions about transportation distances could be worked on further.

Important uncertainties may be related to the estimates of losses in the food sector including long-term storage, retailers and households. Studies of pathways for second grade products, or products originally destined for humans but sold as fodder would help improve allocation and loss estimates in further studies of resource use in the food sector.

It is also important to remember that some life cycle stages left out of this analysis may be important energy contributors when compared to the energy use calculated here. Transportation from retailers to consumers homes can be almost as energy demanding as transportation from farms to retailers (Swedish Environmental Protection Agency, 1997), but that depends on vehicles used, distances travelled and purposes of trips. During dishwashing, hot water requires energy inputs. Our impression is that less hot water is needed for washing the plastic bowls used in microwave ovens than for the pots used on hotplates. Measurements of water use during dishwashing are necessary for knowing whether energy use for heating this water is an important contributor or not compared to other stages in the life cycle.

4.2 Energy use for cooking in households compares to industrial processing.

One important result from our study is the energy use for cooking in households compared with energy use in industrial food processing. Cooking is carried out in millions of households while food processing takes place in a few thousand Swedish food industries. While energy use in industry receives attention in voluntary programs and other initiative launched by Swedish authorities (e.g. the EKO energy programme, Lindén and Carlsson-Kanyama, 2000), energy use for cooking is an activity that receives much less attention and support. Our results (Table 11) show the importance of highlighting cooking as part of other activities for increasing energy efficiency in the food sector.

Table 11: Energy use for industrial processing and cooking in households. In MJ per kg output according to type of process and food.

TYPE OF PROCESS	INDUSTRIAL PROCESSING, MJ/KG OUTPUT	COOKING IN HOUSEHOLDS, MJ/KG OUTPUT
Steaming whole wheat/ cooking whole wheat	0.8	0.9 – 3.8
Making spaghetti/ cooking spaghetti	2.2	3.1 – 4.9
Making fresh pasta/cooking fresh pasta	1.1	1.9 – 3.2
Cutting barley/ cooking barley	0.13	0.9 – 4.0
Polishing rice/ cooking rice	0.02	0.7 – 3.5
Fabrication of couscous/cooking couscous	2.6	0.2 – 0.9

Our study also shows that there is considerable scope for altering energy use for cooking. Realising such changes in households will depend on e.g. convenience, skill, size of households and price of energy and kitchen appliances. In the on-going project, Urban Households and Consumption Resource Related Use, such aspects will be investigated with the aim of proposing sets of measures that could help reduce energy use for households' cooking.

4.3 Dietary choices for increased energy efficiency

In total, we have estimated the life cycle energy use for 34 food portions of wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes. Energy use for each portion depend, generally, on factors such as cooking method and mode, appliance, cooking time, degree of processing, storage time, transportation distances and energy use of vehicles, cultivation methods, and energy intensity of agricultural inputs. Energy use during the life

cycle is thus determined by how resources are used in a number of dimensions related to time and space.

When the energy estimates for the 34 portions analysed in our study are sorted it is easy to see that there is a large span in energy use over the life cycle (Figure 11). Such energy use varies from 0.33 MJ to 6.0 MJ per portion.⁹ The lowest value was found for a portion of wheat cooked on a hotplate as part of 4 portions and the highest value for a portion of potatoes baked in a conventional as a single portion. Three food groups can be distinguished based on the energy use per portion presented in Figure 11: In the first group where MJ per portion is below 0.7 MJ per portion there are seven examples, of barley and whole wheat. In the second group, where energy use is between 0.7 MJ and 1.2 MJ per portion we find 15 examples. These examples include potatoes, spaghetti, rice, mashed potatoes and couscous. In the third group where energy use is more than 1.2 MJ per portion there are 11 examples. They include fresh pasta, spaghetti from Italy and portions of rice, spaghetti and boiled potatoes cooked as single portions. Baked potatoes also fall within the category of food items with a higher total energy use than 1.2 MJ per portion.

As was pointed out in the Introduction, the foods selected for this study can and are being substituted for one another. We have demonstrated that there are possibilities for more energy efficient diets by increasing the consumption of whole wheat and barley, by cooking four portions at one time, by using an electric kettle for cooking couscous and mashed potatoes and by using a microwave oven instead of a conventional oven for cooking potatoes. Further research with focus on households' skill, time constraints and availability of products and appliances will be necessary for judging the feasibility of such substitutions on a large scale.

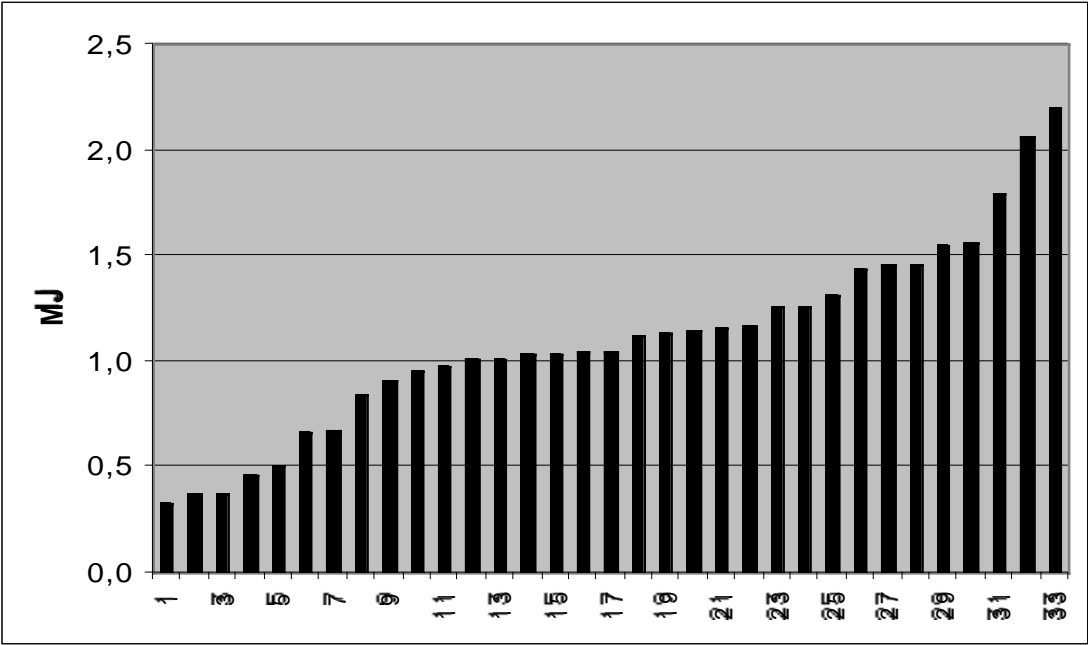


Figure 11: Life cycle energy use for 33 portions of wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes. In MJ per portion according to cooking mode, food item and number of portions. For a full explanation see Appendix B.

⁹ The example with one portion of potatoes baked alone in a conventional oven is excluded from the figure.

4.4 Further research on energy use for cooking

Further research about energy use for cooking could proceed along several lines. Some suggestions are given below:

- Differences in electricity use between conventional ovens and microwave ovens could be explored further. Microwave ovens have a wide use for cooking. Frying and baking is possible if they have a crisp function. What difference would it make if households fried all their meatballs and baked all their cakes in microwave ovens?
- Differences between cooking food on hotplates and cooking food by using a combination of electric kettles and hotplates seem to offer substantial possibilities for reductions in electricity use. The electricity use for boiling water in the kettle was close to the specific energy use for water. What difference would it make if households cooked all their spaghetti by first heating water in an electric kettle and then used the hotplate for boiling the spaghetti?
- Differences in energy use between cooking for one or several households should be investigated. What difference does it make if cooking alternates in clusters of households? Such arrangements already exists in several housing units in Stockholm and elsewhere.
- Differences in energy use when food is cooked with less water than in our trials could be investigated, although food quality would then have to be considered as well.

5. Conclusions

- Electricity use for cooking can be a large or dominating part of total energy use in some food products' life cycles. Such food products are preferably of vegetable origin with a low to medium degree of processing.
- Electricity use during cooking is highly influenced by the choice of cooking appliance. A hotplate was more efficient than a microwave oven with a sensor regulated simmering function for boiling wheat, barley and rice. An electric kettle was more efficient than a hotplate for boiling the water needed to prepare couscous and mashed potatoes from mashed potato powder. The electricity use for boiling water in an electric kettle compares with the specific heat for water. A microwave oven was much more efficient than a conventional oven for baking potatoes.
- It was always more energy efficient to prepare several portions at the same time. The differences were in the order of a factor two to three for wheat, barley, rice, potatoes, couscous and mashed potatoes. For spaghetti and fresh pasta the differences were smaller.
- Energy use for households' cooking compares with energy use for industrial food processing.
- There seem to be large possibilities for improving the energy efficiency of diets with respect to choice of ingredient and cooking mode. Our study indicates that one portion of food commonly served as a part of a hot meal can be produced with life cycle energy inputs ranging from 0.33– 6.0 MJ per portion.

References

- Carlsson-Kanyama and Faist. 2000. Energy Use in the Food Sector: a data survey. AFN report 291, Swedish Environmental Protection Agency, Stockholm, Sweden.
- Carlsson-Kanyama. A. 1998. Energy consumption and emissions of greenhouse gases in the life cycle of potatoes, pork meat, rice and yellow peas: methods, data and results from a study of some food consumed in Sweden. With arable land use and re-calculated energy consumption and emissions of greenhouse gases for carrots and tomatoes. Technical report No. 26, Department of Systems Ecology, Stockholm University, Sweden.
- Carlsson-Kanyama A. 1999. Consumption Patterns and Climate Change: consequences of eating and travelling in Sweden. PhD thesis, Department of Systems Ecology, Stockholm University, Sweden.
- Cerealia AB. 2000. Personal communication with Bengt Spetz, Slobodan Carapic and Jörgen Swahn.
- Dutilh C.E and Kramer K.J. 2000. Energy Consumption in the Food Chain: comparing alternative options in food production and consumption. In *Ambio* Vol. 29 No. 2, March.
- Frebaco kvarn. 2000. Personal communication with Ingegärd Irebäck..
- IPCC, Intergovernmental Panel on Climate Change. 1996. *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge, New York.
- IPCC, Intergovernmental Panel on Climate Change. 1998. *Regional Impacts of Climate Change: an assessment of vulnerability*. Cambridge University Press, Cambridge, New York.
- Kuik A. 1998. Energy saving while cooking potatoes. Unpublished document from the Swedish Consumer Agency.
- Lindén A-L and Carlsson-Kanyama A. 2000. Hinder och incitament för energieffektivisering inom industrin- en utvärdering av program EKO-energi. Final report accepted by STEM in October 2000. In Swedish.
- Mått för Mat. 2000. ICA bokförlag, Västerås, Sweden. In Swedish.
- Heiss, R. (Ed.) 1996. *Lebensmitteltechnologie. Biotechnologische, chemische, mechanische und thermische Verfahren der Lebensmittel-verarbeitung*. Berlin, Heidelberg, Springer Verlag, Germany.
- Johansson S. 1998. Förstudie av energiflöden och energiutnyttjande på spannmålgårdar i MellanSverige. Ett projekt utfört på uppdrag av LRF. Jordbrukstekniska institutet, Uppsala, Sweden. In Swedish.
- Kocktürk T. 1998. Food habit changes among immigrants in Sweden. In *Food and the traveller* (ed. P. Lysaght). Intercollege Press. Pp161-66.
- Nordmills. 2000. Personal communication with Jan Lind.

NFA, National Food Administration. 1985. Svinnet i livsmedelshanteringen. In Swedish.

NTM, Network for transportation and the environment [URL:adress http://www.ntm.a.se](http://www.ntm.a.se)

Olsson P. 1998. Ärtor eller fläsk? En energijämförelse från jord till bord av fläskkött och olika baljväxter. Rapport 4909, Swedish Environmental Protection Agency, Stockholm, Sweden. In Swedish.

SLU, Swedish University of Agricultural Sciences. 1996. Databok för driftsplanering 1996. Speciella skrifter 62, Uppsala, Sweden. In Swedish.

Stadig M. 1997. Livscykelanalyser av äppleproduktion: fallstudier för Sverige, Nya Zeeland och Frankrike. SIK Rapport 630, Swedish Institute for Food and Biotechnology, Gothenburg, Sweden. In Swedish.

Swedish Board of Agriculture. 2000. Konsumtionen av livsmedel m.m. 1996-1999. Report 2000:13, Jönköping, Sweden. In Swedish.

Swedish Environmental Protection Agency, Naturvårdsverket. 1997. Det framtida jordbruket - slutrapport från systemstudien för ett miljöanpassat och uthålligt jordbruk. Stockholm, Sweden. In Swedish.

Swedish RiceAB. 2000. Personal communication with Hasem Kurda.

Procordia Foods. 1998. Personal communication with Björn Örnskär.

Uhlin H-E. 1997. Energiflöden i livsmedelskedjan. Rapport 4732, Swedish Environmental Protection Agency, Stockholm, Sweden. In Swedish.

Wasabröd. 2000. Personal communication with Lars-Olof Nordqvist.

Appendix A

Tests were performed to measure energy consumption, time and temperature were also recorded.

1. Use of different heat sources.
2. Cooking amount, one portion and four portions.

1. Different heat sources; Instrumentation

- Solid hot plates. Electric hob with four hotplates T- 2004. Two hotplates were in use for this project, one small \varnothing 145 mm at 1500 W and one bigger \varnothing 180 mm at 2000 W. Vessels of two different sizes were used, T-2011 for 145 mm and T-2013 for 180 mm both made by Hackman.
- Electric kettle T- Krups 691, 1850 \pm 10 W
- Microwave oven. Whirlpool MT 226, Object 00-34. 2200 W, microwave effect 865 \pm 5 W. Data acquisition and evaluation system, Easy View, data logger Intab AAC-2 and energy meter Enermet K420NNS, thermocouple type J. System calibration.

The estimated total uncertainty of the measurements are:

Energy measurements: \pm 2 %

Temperature: \pm 2 °C

Weight: \pm 0 gr.

2. Cooking amounts.

Rice pasta, wheat, potatoes, barley and couscous were prepared according to size of portion described on the packing or when not accessible the amount was taken from “Mått för mat” (measurements, weight, time and temperature when cooking food).

Start temperature for water was 15 \pm 1°C and for the food, ambient temperature at 23 \pm 2°C

Each measurement was performed at least twice.

Energy consumption for preparation of couscous and mashed potato was calculated from a separate test of time and energy consumption for boiling water at a solid hot plate compared to boiling in a electric kettle.

Rice

- One portion 60 gr. rice and 150 gr. water, total cooking time: 20 min at hob and 17 in microwave oven
- Four portion 240 gr. rice and 600 gr. water, total cooking time: 20 min at hob and 17 in microwave oven

Pasta

- One portion 70 gr. spaghetti and 1000 gr. water, total cooking time :14 min
- Four portion 280 gr. spaghetti and 2500 gr. water, total cooking time:18 min
- One portion fresh pasta 130 gr. and 1000 gr. water, total cooking time:8 min

- Four portions fresh pasta 520 gr. and 2500 gr. water, total cooking time:12 min

Wheat

- One portion prepared on hot plate, 45 gr. wheat and 88 gr. water, total cooking time 15 min.
- One portion prepared in microwave oven, 45 gr. wheat and 85 g water, total cooking time 12 min.
- Four portions prepared on hot plate, 180 gr. wheat and 350 gr. water, total cooking time 17 min
- Four portions 180gr. wheat and 350 gr. water prepared in microwave oven, total cooking time 15 min.

Potatoes

- One portion boiled potatoes: 190 gr. potatoes and 600 gr. water, total cooking time for conventional method 28 min and 20 with an energy saving method.
- Four portions boiled potatoes: 800 gr. potatoes and 1000 gr. water, total cooking time for conventional method 32 min and 24 with an energy saving method.
- One portion for baked potatoes 300 gr. Baking time in microwave oven 7 min and in conventional oven 65 min
- Four portions baked potatoes 1200gr. Baking time in microwave oven 28 min and in conventional oven 65 min
- One portion mashed potatoes 35 gr. powder and 175 gr. boiling water, cooking time for the water 2 min 15 sec on hot plate and 50 sec boiled in electric kettle
- Four portions mashed potatoes 140 gr. powder and 650 gr. boiling water, cooking time for the water 4 min 15 s on hot plate and 1 min 50 s boiled in electric kettle

Barley

- One portion 40gr. barley and 175 gr. water, cooking time on hot plate 30 min.
- One portion 40gr. barley and 160 gr. water, cooking time in microwave oven 23 min.
- Four portions 160 gr. and 700gr. water, cooking time on hot plate 30 min.
- Four portions 160 gr. and 700gr. water, cooking time in microwave oven 26 min.

Cous-cous

- One portion 80 gr. cous-cous and 100 gr. boiling water, cooking time for the water 2 min on hot plate (too small amount to boil in an electric kettle)
- Four portions 240 gr. cous-cous and 300 gr. boiling water, cooking time for the water 2 min 25 s on hot plate and 1min boiled in electric kettle.

Appendix B

NUMBER	FOOD ITEM WITH APPLIANCE, COOKING MODE AND METHOD	MJ LIFE CYCLE ENERGY USE PER PORTION
1	wheat, hotplate, 4 portions	0.33
2	barley, hotplate, 4 portions	0.37
3	wheat, microwave oven, 4 portions	0.37
4	barley, microwave oven, 4 portions	0.46
5	wheat, hotplate, 1 portion	0.51
6	barley hotplate, 1 portion	0.66
7	wheat, microwave oven, 1 portion	0.67
8	potatoes hotplate, 4 portions, energy saving method	0.85
9	potatoes, hotplate, 4 portions	0.91
10	barley, microwave oven, 1 portion	0.95
11	couscous, electric kettle, 4 portions	0.97
12	couscous, electric kettle, 1 portion	1.0
13	mashed potatoes, electric kettle, 4 portions	1.0
14	rice, hotplate, 4 portions	1.0
15	couscous, hotplate, 4 portions	1.0
16	mashed potatoes, electric kettle, 1 portion	1.0
17	mashed potatoes, hotplate, 4 portions	1.1
18	couscous, hotplate, 1 portion	1.1
19	rice, microwave oven, 4 portions	1.2
20	Swedish made pasta, 4 portions	1.2
21	potatoes, hotplate, 1 portion, energy saving method	1.2
22	mashed potatoes, hotplate, 1 portion	1.2
23	Italian made pasta, 4 portions	1.3
24	rice, hotplate, 1 portion	1.3
25	potatoes hotplate, 1 portion	1.3
26	potatoes, microwave oven, 4 portions	1.4
27	Swedish made pasta, 1 portion	1.5
28	potatoes, microwave oven, 1 portion	1.5
29	rice, microwave oven, 1 portion	1.5
30	Italian made pasta, 1 portion	1.6
31	fresh pasta, 4 portions	1.8
32	fresh pasta 1 portion	2.1
33	potatoes, conventional oven, 4 portions	2.2
34	potatoes, conventional oven, 1 portion	6.0