Energy consumption by cooking appliances used in Polish households

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Abstract. The purpose of the study was to compare the energy consumption of food processing equipment in the context of the sensory characteristics of the dishes prepared in them. The paper presents energy consumption analysis of household appliances for food heat treatment. To determine the real parameters of the thermal processing of food laboratory experiment was carried out. The following appliances were compared: electric hobs with steel plate and ceramic plate and induction, gas hobs, microwave oven, steam cooker and Thermomix. Energy consumption, cooking time and cooking temperature were determined. The influence of different thermal treatments on the taste, flavour and colour of boiled potatoes was also compared. Cooking time of 200g potato portions ranged from 6 min in microwave to 26 min for cooking in water in Thermomix. Potatoes boiled in water and in steamers in normal pressure had the best sensory properties, the worst - from microwave. Unit energy consumption was the highest in steam cooker. Cost analysis has shown that the use of electric heating appliances is 60 to 380% more expensive than gas hobs. Using pressure cooker instead of pot saves 33.3% of electricity and 17.4% of gas.

1. Introduction
Rational use of energy is aimed at lower exploitation of the environment, by reducing its consumption, by increasing the energy saved. When analysing the issue of rational use of energy, industrial objects are usually considered. Meanwhile, individual households use a large proportion of their energy to heat, illuminate, warm up, and prepare meals.

According to statistics in Poland there are about 13.4 million households [1]. The largest groups are small, single and double (24% and 25.8%, respectively), the smallest over 5 persons (6.4%). Polish households use the most energy for: heating of premises 526547 TJ, water heating 129861 TJ and for cooking meals 68564 TJ [1].

High energy consumption for preparing meals is due to the fact that it is customary to prepare and consume at home. Dining out in the workplace and mass caterers are rarely practiced on a daily basis. It usually refers to exceptional family celebrations involving more than one person. An average family in Poland spend about 5.3% of food expenditure on out-of-home nutrition, while in the United States, food expenditure in catering establishments’ amounts to 51.0% of total nutrition expenditure [2]. At present, an average Polish consumer uses the restaurant only a few times a year, whereas in Western European countries the frequency is much higher, eg the French - 70 times a year, the American practically every other day [2]. The reasons for not using gastronomy are primarily the financial barrier and the habit of eating at home. On the other hand, home meals are much more beneficial to the consumer. They are fresh, have desirable flavour characteristics, and are not previously stored or

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reheated, which makes them safer microbiologically and carry less health risk. Home meals do not contain preservatives or other technological additives that are used in industrial food production to stabilize the quality and durability. It has also been proven that the preparation of food with fresh ingredients is associated with lower energy use than the use in processed food [3]. Total energy consumption per portion for each meal type (ingredients, wholesale, production, usage, packaging, waste treatment, transport), is the highest in ready to eat meals - about 22 MJ per portion in total. In case of meals prepared from fresh ingredients are 13 MJ and semi prepared meals 12 MJ [3]. Thus, homemade meals have a rational aspect. The authors also pointed out that meals prepared at home are not so much wasted, not eaten to the end as ready meals. [3]. In light of these facts, an important issue is the analysis of energy consumption for the preparation of home meals and its rationalization. It is important to increase awareness of energy management in the household and at the same time spending on it.

Scientific studies on energy consumption indicate ways of rational conduct during food preparation[4-9]. The studies compared energy consumption and indicated savings in the use of specific equipment.

Oberascher, Stamminger and Pakula [5] indicated the possibility of saving 50% of energy when boiling water in electric kettle instead of a pot on electric stove, and when brewing coffee in a coffee machine instead of brewing manually with water boiled in a pot. Saving 70% of energy is possible when vegetables are cooked in small amounts of water, and energy is reduced as soon as the water starts boiling and the pot is covered with a lid. Reducing 60% for boiling eggs is possible using an egg cooker instead of a pot without a lid.

According Das et al., [6] using a rice cooker instead of a pot allows for 77% energy saving and using a pressure cooker lowers energy consumption by 42%. Wyczółkowski and Urban [7] had shown that covering a pot with a lid increases the efficiency of water heating from 12.2 to 15.9% and that the highest efficiency of heating is when electric kettle is used. Covering the pot with a lid allows saving over 12% of energy by limiting water evaporation [8]. The cooking efficiency increases with the size of the pot and the amount of water in the pot [9].

The studies analysing energy consumption for food processing do not take into account the influence of the technological process on the sensory characteristics of the meal. Food preparing methods depend essentially on many factors such as the availability of equipment, nutritional needs, preferences, taste smell and texture as well as eating habits and culinary traditions.

In this work different methods of cooking potatoes as a typical component of a conventional dinner were subjected to a comparative analysis. Available household appliances were used for cooking in water, steam at atmospheric pressure, in steam overpressure and in a microwave. In addition, the influence of the cooking method on sensory characteristics of potatoes was assessed. The aim of the study was to compare the energy consumption and cooking cost in the context of the sensory quality of cooked potatoes.

2. Domestic appliances for preparing hot meals

| Cooking appliances | Type of heating plate | Efficiency [%] | Power [W] |
|--------------------|----------------------|----------------|-----------|
| gas cooker         | stove burners        | 55 - 58        | 6600 - 7200 |
| electric cooker    | steel                | 55             | 2000      |
| electric cooker    | ceramic              | 60             | 2000      |
| induction cooker   | ceramic              | 90             | 5800-7400 |
| steam cooker       | -                    | -              | 800 - 2000 |
| slow cooker        | -                    | -              | 160 - 220  |
| cyclojet           | -                    | -              | 1200 - 1300 |
| Thermomix          | -                    | -              | 500       |
Many home appliances for cooking use a variety of gas or electric panels. Gas stoves are powered by natural gas or LPG. Electric hobs can have different types: steel or cast iron, ceramic or inductive. In Poland, they can be powered by electricity 230V or 400V. Other devices, such as steamers, pressure cookers, cyclojets or Thermomixes, and more can also be used.

The most common heat treatment appliances in Polish households include electric-gas cookers in which hob are powered by gas and an oven is supplied by electricity (Figure 1). In the second place in terms of frequencies are gas-powered cookers. Microwave ovens are a complement to kitchen equipment and are found in 58% of households. They do not completely substitute electric and gas cookers. Apart from a few cases, it is not the only cooking equipment [1], most often used for reheating and defrosting [10].

![Figure 1. Equipment for cooking meals in Polish households [1].](image)

In the years 2002-2015, there was a widespread use of electric cooking utensils. The share of households with gas-electric stoves increased from 25% to 57.7%, and the share of households with microwave ovens from 23.6% to 58% [1].

The efficiency of thermal processing equipment (understood as a% of energy directly used for heating food) is varied. The efficiency of domestic appliances declared by manufacturers is the following: induction hobs - 90%, electric ceramic hobs - 60%, gas plates with individual burners 55-58%, electric iron hobs only 55% [11].

### 3. Materials and methods

#### 3.1. Raw materials

The research material in the experiment was potatoes. The size of the bulbs ranged from 30 to 80g. Potatoes were peeled and cut into pieces weighing 20 - 35 g. 200 g potatoes were used for cooking. The 200g portion was defined as optimal for small households. The potatoes used in the experiments came from the same stock.

#### 3.2. Equipment and experimental procedure

A potato cooking experiment was conducted using a variety of methods with different devices. Potatoes are cooked in water, in steam under normal pressure, in steam under high pressure, and in the microwave. Kitchen plates (gas, steel, ceramic, inductive) and Thermomix (option I - cooking at 100 °C) were used to cook potatoes in water. Steamer and Thermomix (option II – Varoma program) were used to cook potatoes under normal pressure. For steam cooking under pressure, a pressure cooker and electric steel plate were used. Cooking in water was done in the same way with each cooking hob. First, 450 ml of cold water at 22 °C was poured into the pan and covered with a lid, set on the heating plate and switched on. When the water temperature was about 98.5°C, potatoes were added to the boiling water, and also cooked under cover. The time to boil water and potato cooking time were measured. For cooking in the water was used a pot of 18/10 stainless
steel with an acutermal bottom and a cap with a capacity of 1,750 l, bottom diameter 15 cm, height 10 cm and thickness of bottom 1 cm. The weight of the pot was 515 g, the weight of the lid was 180 g. In case of Thermomix (option I - cooking at 100 °C), 1400 ml of water was poured into the structure, and potatoes were immediately placed in a submerged basket and the time to complete cooking was measured. The cooking time in the pressure cooker was set to reach overpressure and boil potatoes under pressure. In each case the cold water temperature was 22 °C. The used appliances and cooking parameters are listed in table 2. Due to the small variability of the results the experiment was repeated three times.

Table 2. Characteristics of the equipment used and the experimental conditions.

| Type of cooker          | Type of supply power | Utensil          | Burner size [cm] | Amount of water [ml] |
|-------------------------|----------------------|------------------|------------------|----------------------|
| **Cooking in water**    |                      |                  |                  |                      |
| Electric cooker         |                      |                  |                  |                      |
| with steel plate        | Electricity 230V     | Pot with lid     | 15.5             | 450                  |
| Electric cooker         |                      |                  |                  |                      |
| with ceramic plate      | Electricity 400V     | Pot with lid     | 14.5             | 450                  |
| Induction cooker        |                      |                  |                  |                      |
| with steel plate        | Electricity 230V     | Pot with lid     | 15**             | 450                  |
| Termomix I              |                      |                  |                  |                      |
| Gas cooker              |                      |                  |                  |                      |
|                       | Electricity 230V     |                    | 5.5              | 450                  |
| **Cooking in the microwave** |                      |                  |                  |                      |
| Microwave               | Daewoo KOR – 1825    | Electricity 230V  | HRG              | 20                   |
|                         | microwave power 900W |                  |                  |                      |
| **Steaming at normal pressure** |                      |                  |                  |                      |
| Steam cooker            | Tefal S02            | Electricity 230V  | -                | 1000                 |
|                         | Power 650 W          |                  |                  |                      |
| Termomix II             | TM5                  | Electricity 230V  | Varoma           | 450                  |
| **Steaming under increased pressure** |                      |                  |                  |                      |
| Electric cooker         |                      |                  |                  |                      |
| with steel plate        | Electricity 230V     | PC               | 15.5             | 120                  |
| Gas cooker              | Amica 58GGD1.23OFP   | Natural gas      | PC               | 5.5 120              |

* Maximum power level
** In the induction cooker the size of the heater is equal to the size of the bottom of the pot
HRG - Heat resistant glass dish 1 l with lid; PC-pressure cooker Fisslervitavit 6 l

Potato cooking time was determined experimentally based on sensory evaluation of consistency using the verbal scale method [12]. The cooking time was found to be appropriate for the consistency of 8 out of 10 evaluators. Measurement of electricity was made using the digital meter FHT 9999 EMOS. Measurement of the volume of the gas spent was made using the BK-G meter 1.6M. For the calculation of the cost of energy consumption, the average price of 1 kWh of G11 electricity was PLN 0.55 = 55 gr. For the calculation of the gas price, the average rate for 1 m³ of gas was PLN 1.5 = 150 gr. This price was in Poland in July 2017.

3.3. Evaluation of sensory quality

Cooked potatoes were subjected to 5-point sensory evaluation [13]. The rating was made by a 10-person team with proven sensory sensitivity [14]. The colour, flavour and taste of potatoes cooked in water, in steam under pressure - in a pressure cooker, in steam under normal pressure and in a
microwave were compared. The overall quality of potatoes as a weighted average was calculated using the following discriminants weighting: colour - 0.25, flavour - 0.25, taste 0.5.

4. Results and discussion

The results of the experiments indicate that the cooking methods of potatoes affect the length of cooking time, energy consumption and cost. The total cooking time of 200 g potatoes was from 6 to 26 min (table 3). The shortest cooking time was in the microwave, the largest in the steamer and in the Thermomix in large quantities of water. Electricity consumption was the lowest with the pressure cooker which was 100 W, the highest was 300 W using the steamer.

Table 3. Cooking time, energy consumption and cost of different methods preparing 200g of potatoes.

| Method                              | Cooking time | Electricity consumption | Gas consumption | Energy costs |
|-------------------------------------|--------------|-------------------------|-----------------|--------------|
|                                     | to boiling water | Cooking potatoes | Total cooking | [kWh] | [m³] | [gr] |
| Steel plate                         | 6            | 18                      | 24              | 0.15         | -    | 8.25  |
| Ceramic plate                       | 5            | 18                      | 23              | 0.13         | -    | 7.15  |
| Induction cooker                    | 3            | 13                      | 16              | 0.21         | -    | 11.55 |
| Gas cooker                          | 5            | 15                      | 20              | -            | 0.023| 3.45  |
| Termomix I* (100 °C)                | -            | -                       | 26              | 0.22         | -    | 12.10 |
| Microwave oven                      | -            | 6                       | 6               | 0.22         | -    | 12.10 |
| Steam cooker                        | 25           | 25                      |                 | 0.30         | -    | 16.50 |
| Termomix II**                       | -            | 24                      |                 | 0.27         | -    | 14.85 |
| Steel plate with PC                 | 6            | 8                       | 14              | 0.10         | -    | 5.50  |
| Gas cooker with PC                  | 4            | 8                       | 12              | -            | 0.019| 2.85  |
| PC – pressure cooker                |              |                         |                 |              |      |       |

Taking into account the current prices of electricity and natural gas on the Polish market, the cheapest way to cook is on the gas with the use of pressure cooker, and the most expensive is cooking in the steamer. Referring generated costs to the cost of traditional potatoes cooking in a pot on the gas these proportions developed in the range between 0.83 and 4.78 (Figure 2). That means that cooking in a steamer is 378% more expensive than traditional cooking on gas. Approximate prices for potato cooking are with the use of microwave and induction cookers. Among cooking appliances supplied with electricity the least energy consumption had cookers with a ceramic plate and with a steel plate. Cooking in a pressure cooker leads to the significant reduction energy costs.

The use of pressure cookers in the experimental conditions saved 33.3% of electricity and 17.4% of gas. It should be noted that the pressure cooker used in the experiment had a capacity of 6 liters, and the capacity of pot was just 1.75 liters. The use of a pressure cooker with a smaller capacity would make it even more energy efficient.
Figure 2. Cost of cooking potatoes in different methods and in different appliances compared to the cost of cooking on a gas hob.

The cooking process significantly influences the sensory properties of potatoes. Potatoes boiled in water were most advantageous and received a total quality score of 4.29 points on a 5 point scale (Figure 3). They had the highest ratings of all evaluated marks in the range of 4.15 to 4.38 points. Potatoes cooked under steam at normal pressure were also highly evaluated - overall quality was 4.20 points, evaluation of individual features ranged from 4.12 to 4.15 points. The lowest rating for overall quality – 3.61 points was obtained with microwave cooking mainly due to darkening of the surface and deterioration of colour. Potatoes cooked in a pressure cooker were evaluated at a similar level of quality – 3.63 points mainly because of their unpleasant flavour. Considering these results, boil in water and steam at normal pressure are the best methods for potatoes.

Figure 3. Sensory properties of potatoes cooked different methods.
The rational way of cooking should indicate the optimum method for obtaining the best taste, flavor, colour and consistency, the highest nutritional value with the least amount of energy and time needed for preparation. In case of potato cooking, the combination of these conditions does not clearly indicate the best method of thermal treatment. Cooking in water under normal pressure gives potatoes the best taste, smell and color. Cooking in water, however, causes a significant loss of soluble components such as vitamin C and minerals, especially potassium [15]. The smallest losses of these components occur during heat treatment without the use of water or steam, i.e. during microwave and steam cooking. At the same time, steam cooking under pressure due to shorter process time allows for less loss of vitamin C. Sensory properties of potatoes cooked with these methods are evaluated low, due to the worse colour and flavor compared to those cooked traditionally in water. Using gas hobs is more economical than electric hobs because of lower gas prices. Traditional cooking on electric cookers is more than twice as expensive as cooking on gas cookers. The lowest electricity consumption for cooking potatoes is achieved by electric cookers with ceramic and steel plates. In the conducted experiment cooking in the gas hobs turned out to be the cheapest while cooking in the steamer and Thermomix were the most expensive. Steam cooking compared to cooking in the gas hobs is almost four times more expensive. Cooking for pressure cookers can save energy, but the sensory quality, especially the flavor of potatoes is low. The most economical ways to cook potatoes with the best sensory properties are cooking on the gas cooker followed by electric cookers with steel or ceramic plates.

5. Conclusion
Preparing meals in a rational way, it is essential that they are tasty and healthy. Aspects those are equally important is the time needed for preparation and the cost of energy used for this purpose. The experiment allowed to compare the sensory characteristics of potatoes cooked in different ways, cooking time and the cost of energy used for cooking. Among the methods of traditional cooking in water, which allow receiving a dish with the best sensory characteristics, the most rational should be cooking on gas stoves due to the lowest cost and moderate duration of the process. The least effective for this purpose is the use of Thermomix, due to the long process time and high energy consumption. Assessing cooking on electric cookers, it is better to use the cooker with an induction hob due to the shorter cooking time compared to stoves with a steel or ceramic plate. From the other cooking methods (small proportion of water) to the most rational include cooking under increased pressure using a pressure cooker. This method allows to quickly and cheaply cook a dish with slightly worse sensory characteristics compared to boiled in water. The use of microwave ovens allows to get boiled vegetables in the shortest possible time and low energy consumption, however, with the worst taste and flavour. Cooking potatoes in a steamer or in Thermomix gives a product with very good sensory characteristics, but the time of preparation is the longest and it is accompanied by high energy consumption.

References
[1] Energy consumption in households in 2015 2017 Statistical Information and Elaborations. Warsaw pp 75
[2] Gheribi E 2013 Marketing i Rynek 4 pp 29-35
[3] Hanssen O J and Vold M and Schakenda V and Tufte P-A and Møller H and Olsen N V and Skaret J 2017 Journal of Cleaner Production 142 pp 395-402
[4] Cimini A and Moresi M 2017 Journal of Food Engineering 204 pp 8-17
[5] Obersacher C and Stammingger R and Pakula C 2011 International Journal of Consumer Studies 35 pp 201–211
[6] Das T and Subramanian R and Chakkavarthi A and Singh V and Ali S and Bordoloi P 2006 Journal of Food Water 75 pp 56–166
[7] Wyczółkowski R and Urbaniak D and Wyleciel T 2015 Rynek Energii 6 pp 58-64
[8] Newborough M and Probert S D 1987 Journal of Foodservice 4 pp 233-257
[9] Hager T J and Morawicki R 2013 Food Policy 40 pp 54-63
[10] Korzeniowska-Ginter R and Tkacz K 2015 Inżynieria i Aparatura Chemiczna 54 5 pp 257-258
[11] Dziedzic T 2011 *Nafta-gaz* 67 11 pp 804-811
[12] PN-ISO 4121:1998 Analiza sensoryczna – Metodologia – Ocena produktów żywnościowych przy użyciu metod skalowania
[13] Baryłko-Pikielna N and Matuszewska I 2009 Sensoryczne badania żywności Wydawnictwo Naukowe PTTŻ
[14] PN EN ISO 8586 Analiza sensoryczna -Ogólne wytyczne wyboru, szkolenia i monitorowania wybranych oceniających i ekspertów oceny sensorycznej
[15] Pyryt B M 2003 Wpływ metod obróbki kulinarnej na jakość nowych odmian ziemniaków przeznaczonych do bezpośredniego spożycia PhD thesis Akademia Morska w Gdyni