# Analysis of LPG, electric and induction cookers during cooking typical Ecuadorian dishes into the national efficient cooking program

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A B S T R A C T

This research aims to analyze cooking parameters in liquefied petroleum gas (LPG), electric resistance and induction stoves for eight dishes of the Ecuadorian cuisine. During tests, it has been monitored the temperature, time, electrical grid parameters, concentrations of CO and $CO_2$. In addition it has been studied the microbiological and physiochemical changes produced by the thermal treatment in food and a discriminative triangular test for determining the differences in the consumers perception between samples made with induction and LPG based stoves. The results showed which even with an exhaust hood working, there was still a significant value of concentration of CO and $CO_2$ during cooking with a LPG stoves. As a result of these analyses the induction stove shows a better response during the heating process and energy efficiency which have influence in temperatures, taste, vitamin preservation, cooking times, energy consumption and cost to the user.

*Keywords:*
Ecuadorian residential kitchens
Indoor air quality
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Physicochemical measurements
Microbiological measurements
Efficient cooking plan

## Introduction

The quality of food is determined by different aspects such as quantity and quality of nutrients which they contain and health safety. But what will determine the acceptance or rejection of it is related to the subjective perception of consumers, i.e. aspects related to the preference of color, taste, texture, consistency, and presentation of the product (Van Biesen et al., 2010; Tuboly et al., 2003).

Sensory analysis is a multidisciplinary science that panelists use the senses of sight, smell, taste, touch and hearing to measure the sensory characteristics and acceptability of foodstuffs and other materials (Yin et al., 2007; Cheng et al., 2015). There is no other instrument that can reproduce or replace human response; therefore, the sensory evaluation is an essential factor in any study of foods. Sensory analysis is applicable in many sectors, such as product development and improvement, quality control, storage studies and process development (Pari and Vincent-Wayne, 1990; Loutfi et al., 2015). Good examples are the tendency to reduce the content of salt, sugar substitute, and artificial sweeteners or eliminate trans fats for reasons related to health (Samotyja, 2015; Sharma et al., 2013; Gowri et al., 2008; Ennis, 2012). In this case, the investigation was intended to determine whether the sensation produced by food prepared in induction stoves is different from the sensation produced by the same food prepared in LPG stoves. Test of sensory discrimination is a great tool to evaluate the difference after thermal processing.

The microbiological analysis of food is very important to evaluate the content of pathogenic microorganisms and to verify whether different cooking processes are determining whether or not to get food fit for consumption (Todd et al., 2007; Labor, 2004; Yepiz-Gomez et al., 2006). In this paper it has been studied the proposed reduction in the number of pathogenic and spoilage microorganisms after heat treatment between samples made with induction and LPG stoves. Furthermore, it is interesting to study the denaturation of food to know whether people are taking the necessary nutrients degraded or are taking food without proper nutritional values (Todd et al., 2007; Yepiz-Gomez et al., 2006; Thompson, 1994). Finally, it has been desired to know the chemical composition of food made with different cooking instruments.

Indoor air quality (IAQ) can be affected by gases (including carbon monoxide, radon, volatile organic compounds), particulates, microbial contaminants (mold, bacteria), or any mass or energy stressor that can induce adverse health conditions. IAQ in Ecuadorian kitchens is poor due to the lack of ventilation and poor air circulation. Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings (Chanteloup and Mirade, 2009; Santa Cruz et al., 2011).

In recent years, concerns over the IAQ have increased as a result of knowledge about the significance of air quality and thermal conditions on health, comfort and productivity. Several researchers have been performed in order to evaluate the reduction of greenhouse gases and concentration of carcinogenic compound emissions in different stoves during cooking. Indoor levels of particles in developed countries are much lower than in developing countries, and this is generally attributable to the advancement in technology for general household activities and also the use of cleaner fuels (such as liquefied petroleum gas, electricity and natural gas) for cooking and heating (Wouter, 2012; Zhao et al., 2014).

One of the most dangerous gases is carbon monoxide. Potential sources inside a building that may generate carbon monoxide include gas heating systems, gas stoves, gas hot water heaters, cigarette smoke, and portable kerosene heaters (ASHRAE, 2001; Vahlne and Ahlgren, 2014). Levels greater than 5 parts per million (ppm) may indicate the presence of exhaust gases in the indoor environment and should be investigated. Levels of carbon monoxide inside buildings should not exceed 9 or 10 ppm (ANSI/ASHRAE, 2004; Vahlne and Ahlgren, 2014). Another important gas is carbon dioxide. Properly ventilated buildings should have carbon dioxide levels between 600 ppm and 1000 ppm (Koistinen et al., 2001; Indoor Air Quality Standard of China (GB/T 18883-2002), 2002). In order to solve this issue, new technologies are being used to offer a solution for clean cooking. Electricity is part of the solution to achieve clean cooking (Koistinen et al., 2001; Sehjpal et al., 2014). This study investigated the effect of a LPG stoves an electric resistance stove and an induction stove, under an exhaust hood during cooking case-study dishes of eight Cuisines of Ecuador. Concentrations of CO and $CO_2$ have been measured in hood idle or working mode during cooking conditions, to evaluate the reduction of greenhouse gas emissions in an Ecuadorian kitchen.

On the other hand, South America and especially Ecuador has one of the highest levels of solar radiation and pluviosity worldwide, which could be harvested for supplying the region with adequate access to energy. Furthermore, Ecuador is currently building an infrastructure of 3980 MW to use its vast hydropower resource. In this way, it will be able to substitute renewable energy for fossil fuels in its energy mix. The principal use of this new hydroelectric energy will be to develop a world pioneer campaign called "Nati onal efficient cooking plan" (NEFC). The NEFC aims the migration of 3 million of LPG based cookers to electric induction stoves, in order to enhance the security of energy supply and reduce emissions of greenhouse gases and other pollutants (MIPRO, 2015; Villacís et al., 2015).

A cookware manufacturing project for induction stoves is necessary to accomplish these policies, and it is expected to fabricate and use from 2 to 3 million of induction cookware set between 2014 and 2016. The NEFC represents a world pioneer campaign and it aims to develop several adaptations of the electric grid and industry.

In the scope of the NEFC currently, the government of Ecuador subsidizes the LPG. In fact, 15 kg of LPG costs $1.60; on the contrary, in neighbor countries this price is ten or twelve times higher ($16 and $20) (MIPRO, 2015). This means that the total cost of this subsidy for the country is about 690 dollar millions per year and the total cost caused by smuggling around 20%. In addition, about 78% of domestic demand for LPG is imported, which creates dependency and therefore a significant outflow of funds abroad that affect the balance of trade in Ecuador.

In many developing countries, the high costs of modern cooking energy LPG and electricity and their cooking stoves are major constraints for household fuel preferences (Hager and Morawicki, 2013). There are numerous econometric studies on residential energy demand based on studies (Hager and Morawicki, 2013); however, none of them had analyzed this issue in Ecuador. Evaluation of renewable energies, and cooking energy costs and efficiencies, using common cooking energy sources as LPG and electricity, and common food items such as water, oil, and rice are necessary to know the impact of the energy policy in the cooking energy sector (Nesbakken, 1999).

The application of heat alters the composition of food products to enhance taste, texture, digestibility and shelf-life (Hager and Morawicki, 2013). Although cooking is only one aspect of food production, it is essential for the safety of food products and contributes to the digestion, micronutrients and acceptability of food (Tuboly et al., 2003; Vanderzant and Splittstoesser, 1992). From a policy perspective, improvements in all aspects of global food production are necessary to perform sustainable energy practices.

This study performs several microbiological analyses, to know the content in pathogenic and spoilage microorganisms in raw food and after the treatment of food with different cooking technologies. Furthermore, it has been studied the denaturalization of food and its chemical composition in the same way. This research tries to prove that food safety is a significant factor to choose a cooking technology. Moreover, in this research, it has been monitored the temperature, time, electrical grid parameters, in order to determine the different stages of cooking, times of cooking in the different dishes, the energy consumption and the cost to the user. On the other hand, there is no research related to these matter made with typical Ecuadorian cuisine.

## Experimental method

Quito is the capital of Ecuador, which is about 2800 meters above sea level. Consequently, it is a perfect place to investigate the indoor environment in an Andean place or highland during cooking. For this reason the water boils at 92 °C. Culinary laboratories of the Universidad Internacional del Ecuador (UIDE) were selected for taking part in the experiment. No open chimney or other sources of air pollution were found nearby. The studied hood, range and appliances are the typical used in a restaurant kitchen and it has a volume flow rate of 1.2 $m^3$/s. The geometric data of this case-study kitchen are listed in Fig. 1. To perform these tests, exterior windows and interior door in the kitchen remained closed in order to avoid the exhausted air flowing back into the kitchen and it could make the stove flamer flutter which affects the burning efficiency. The most important reason for closing the window and interior door is for assuring the accurate measurement of the pollutants concentration. In this study, it was assumed that the primary air would flow from the crack under the interior doors, with a height of 0.02 m from the floor. The front lower edge of the hood of the case-study kitchen overhang is set to 1.8 m as measured vertically from the finished floor.

The dishes were cooked using three kinds of stoves described as follows:

(1) An electric induction stove of four induction zones, two of 18 cm diameter, one of 14.5 cm diameter and the last one of 21 cm diameter. The nominal power of this device is 7400 W and the nominal voltage of operation is 220 V. However, for the test only one induction zone was used.
(2) An industrial LPG stove SILKO ECG74E of 15,000 W. As this LPG stove is industrial equipment, during the test the power of the cooker burners was limited to 3200 W in order to simulate a domestic stove. This was made by weighting the difference of the gas cylinder on the laboratory scale, when the controls of the stove were at different marks, in order to simulate similar conditions to those obtained with the induction cooker.

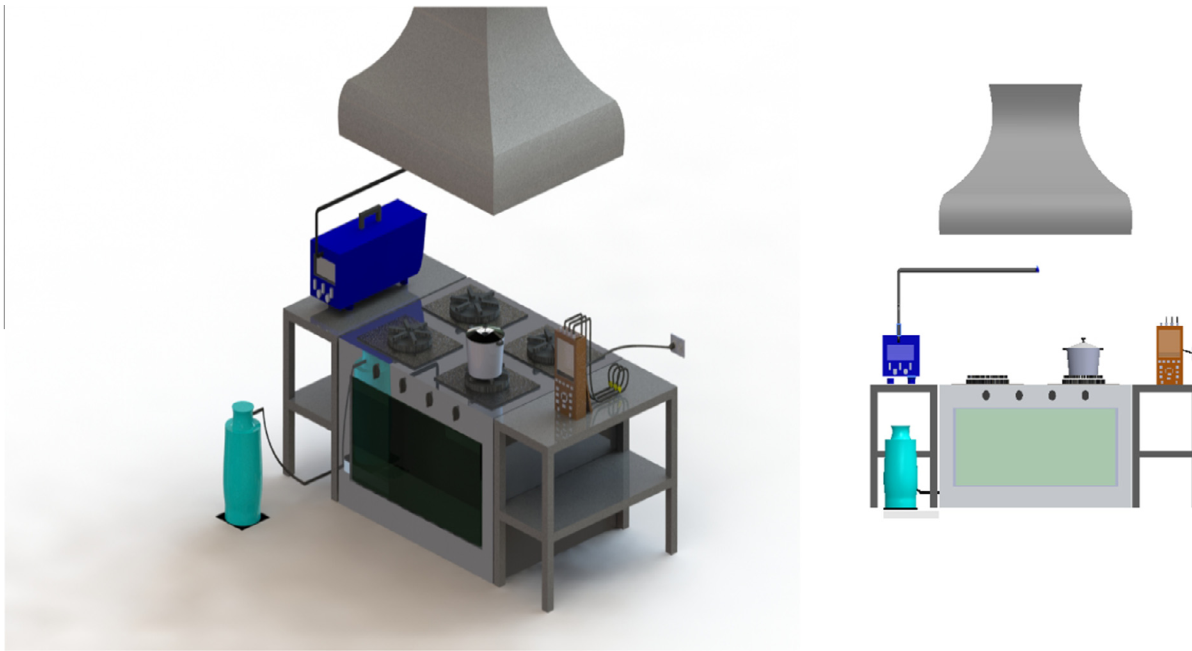


**Fig. 1.** Layout of the case-study kitchen with location of the measurement points.

(3) The electric stove used for tests has two burners with a nominal power of 500 W. The stove characteristics have a direct influence on the test duration, although it was not taken into account when changing any parameter within standards applied to food.

The following experiments were conducted using the observational method applied to one kind of induction pot and one induction pan made of AISI 304 stainless steel in their body and AISI 430 stainless steel in their bottom which is the normal configuration of induction cookware. Each cookware was covered with an AISI 304 stainless steel lid during the tests.

*Case-study dishes and site selection*

The dishes prepared in this study were chosen considering the culinary habits of the Ecuadorian population, chemical composition (macro- and micronutrients), microbiological safety and easy to prepare. The cooked dishes were as follows: hard-boiled egg, grilled chicken, milk, boiled chochos (*Lupinus mutabilis*), steamed fish, boiled broccoli, little orange (*Solanum quitoense*) with oatmeal drink, and Russian salad which has been composed of boiled carrots, potatoes and peas.

The quantity of food was designed to serve lunch for a family between four to six members, except for milk and chochos that were considered for one people. Achiote oil was used as cooking oil. All ingredients and condiments were purchased from a local supermarket, and the amounts used were measured. In order to have the best control of consistency the experiments were repeated three times for each dish. The essential information of each dish is presented in Table 1.

*Procedure of energy cost tests*

In this research, it has been monitored the temperature, time, and electrical grid parameters, in order to obtain the different times of cooking in the different dishes, the energy consumption and cost to the user. For the LPG stove, the weight of the gas cylinder was measured before, during, and after the cooking processes. The energy consumption is represented by Eq. (1), when considering 13,005 kcal/kg as heat of combustion, given by the Quito gas distributor.

$$E\ [\mathrm{kW\,h}] = \frac{\Delta m * PCs}{860} \tag{1}$$

where $E$: is the consumed energy [kW h], $\Delta m$: $(mf - mi)$ is the mass variation of $P$ in [kg], $PCs$: is the heat of combustion of LPG in [kcal/kg].

It was applied a conversion factor between 1 kW h and its equivalent of 860 kcal (Schlomann et al., 2010).

When energy consumption values were measured, the cost of the energy was calculated taking into account a price of \$0.09 per kW h for the electricity and \$20 for a 15 kg cylinder of LPG (MIPRO, 2015). These prices were selected considering the price of the electricity in a house in Ecuador and the international price of a LPG cylinder.

For electric measurements in the electric and induction cookers, the Fluke 430 TF II and the analyzer Sentron PAC3200 of Siemens have been placed on the wires of the electric grid to measure its parameters such as current and voltage. The temperature of the food and time cooking was measured too.

*Procedure of CO and $CO_2$ tests*

In this study indoor air quality analyzer Brain Bee Au Mobile complete mobile unit has been used for emission control to measure the indoor CO and $CO_2$ concentrations. The range of $CO_2$ measurement is from 0 ppm to 15,000 ppm with an accuracy of 1 ppm, and the response time is 1 s. The range of CO measurement is from 0 ppm to 500 ppm with an accuracy of 0.01 ppm, and the response time is 1 s.

The experimental process for measuring the CO and $CO_2$ emissions during cooking was the following: first, it has been closed the interior door and the exterior window, and we turned on the exhaust hood. Then we placed the measuring sensors at the breathing zone of a person (145 cm) in order to measure the background levels of the kitchen indoor environment for a period of 60 s. After that, we started cooking one of the four case-study

**Table 1**
Information of cooking processes and the ingredients of dishes cooked in LPG electric, induction and LPG stoves.

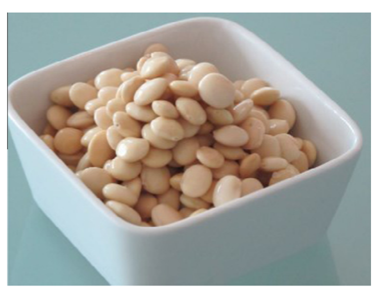
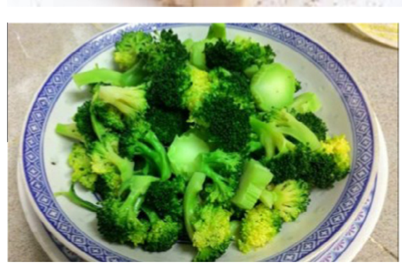
| Dishes | Ingredients | Quantity | Treatment | Picture | Cooking process |
|---|---|---|---|---|---|
| Hard-boiled egg | Eggs<br>Water<br>Salt | 4<br>1 l<br>5 g | |  | • Step 1: Turn on the cooker and heat water until it boils<br>• Step 2: Add all the ingredients in the pot |
| Grilled chicken | Oil<br>Chicken<br>Salt | 40 ml<br>400 g<br>5 g | Fillets |  | • Step 1: Heat up the oil<br>• Step 2: Fry the spiced chicken fillets |
| Milk | Milk | 300 ml | |  | • Step 1: Heat the milk to 75 °C for 15 s |
| Boiled chochos | Water<br>Chochos | 500 ml<br>150 g | |  | • Step 1: Turn on the cooker and heat water until it boils<br>• Step 2: Add the chochos in the pot |
| Steamed fish | Water<br>Fish<br>Salt | 1 l<br>400 g<br>5 g | Fillets |  | • Step 1: Turn on the cooker and heat the water, fish and salt to 75 °C for 5 min |
| Boiled broccoli | Water<br>Broccoli<br>Salt | 1 l<br>10<br>5 g | Flowers |  | • Step 1: Turn on the cooker and heat the water until it boils<br>• Step 2: Boil the broccoli |

**Table 1** (*continued*)

| Dishes | Ingredients | Quantity | Treatment | Picture | Cooking process |
|---|---|---|---|---|---|
| Little orange with oatmeal drink | Water<br>Oatmeal<br>Sugar<br>Orange<br>Cinnamon<br>Clove | 1 l<br>100 g<br>100 g<br>1 piece<br>1 g<br>1 piece | |  | • Step 1: Turn on the cooker and heat the water, the oatmeal, sugar and orange for 18 min |
| Russian salad | Potatoes<br>Peas<br>Carrots | 75 g<br>35 g<br>75 g | Cut in cubes |  | • Step 1: Boil the carrots<br>• Step 2: Boil the potatoes<br>• Step 3: Cook the peas |

dishes of Ecuadorian cuisines and continued measuring the air concentrations of CO and $CO_2$. A sample was collected outdoor. When the cooking process was finished, we continuously measured the parameters until the concentrations in the kitchen reestablished at an acceptable level. Between each experiment, the cookware was washed thoroughly with copious amounts of warm water and with detergent repeatedly.

*Organoleptic measurement*

The discriminative triangular test was used for determining the differences in the consumers perception between samples made with induction and LPG based cookers. One hundred and seven people from National Institute for Energy Efficiency and Renewable Energy of Ecuador (INER) participated (without restrictions or food allergy). They have not been trained in sensory evaluation. In addition, the degrees of difference and acceptance (affective test) were made (Anzaldua, 1994).

In practice three samples were presented to each panelist: two were alike and one was different. The panelist was asked to select the odd sample. The six possible sequences of two dishes were distributed five times in each panel, as shown in Table 2. The samples were evaluated from the left to the right. The food taste was developed between 15:00 and 17:00 in 5 dishes: grilled chicken, steamed fish, cooked broccoli, little orange with oatmeal drink and Russian salad. The samples were served as soon as the cooking process finished, at temperatures and habitual conditions of consumption. Food was served in plastic containers of similar characteristics, in portions of 15 g and 25 ml.

**Table 2**
Sequence distribution of samples during the triangular test.

| Panelist | Sequence distribution | | |
|---|---|---|---|
| | First | Second | Third |
| 1 | A | A | B |
| 2 | A | B | A |
| 3 | B | A | A |
| 4 | B | B | A |
| 5 | B | A | B |
| 6 | A | B | B |

To reduce errors in the results, the panel members were asked to avoid the use of substances with strong odors (soaps, lotions and perfumes); besides, they did not eat or drink (except water) nor smoke at least 30 min before the taste. The evaluation methodology was explained in a written and oral way during the taste. The statistics interpretation of these results was made following the methodologies of Anzaldua (1994) and Standard ISO BS 4120 (2004).

*Physicochemical and microbiological measurements*

Food samples of the three cookers were taken as soon as the cooking process finished for making proximate and microbiological analysis. These samples were analyzed by the accredited laboratory with certify number OAE LE C 09-008. The results were compared with values established in national and international standards in Table 3 (Hernandez, 2010; INEN, 2010, 2012, 2013, 2014; Reyes et al., 1997; Valls et al., 1999; Verdú, 2013).

## Results

In this section the results of the energy consumption, concentrations of CO and $CO_2$, organoleptic, physicochemical and microbiological measurements are presented.

*Results of energy measurements*

The cooking process information is shown in Table 4. For the LPG stove, it has been observed that the cooking time increased between 20% and 396% with respect to the induction stove depending on the dish. This time reduction is related, in most of the cases, to the steps 1 of Table 1, which are the heating processes of water or oil. Energy consumption was incremented by LPG stove between 44% and 170% with respect to induction stove. As energy consumption is reduced, also the cost for the final user is reduced. A raise between 41% and 167% was found when comparing the LPG stove with the induction stove, considering the real price of the LPG without subsidy.

**Table 3**
Cooked dishes and preparation processes.

| Dish | Process | Reference |
|---|---|---|
| Hard-boiled egg | Boil egg for 480 s | On Food and Coking Harold Mc Gee[a] |
| Grilled chicken | Fry chicken until it gets to an internal temperature of 72 °C | On Food and Coking Harold Mc Gee |
| Milk | Heat milk to 75 °C for 15 s | Ecuadorian National Standard NTE INEN 10:2012 |
| Boiled chochos | Boil the chochos for 180 s until it is pasteurized and the bitter flavor is gone | On Food and Coking Harold Mc Gee |
| Steamed fish | Turn on the cooker and heat water, fish and salt until it gets to 75 °C for 5 min | On Food and Coking Harold Mc Gee |
| Boiled broccoli | Boil broccoli until it becomes soft | |
| Little orange with oatmeal drink | Turn on the cooker and heat it up for 18 min | |
| Russian salad | Boil the vegetables until they become soft | |

[a] H. Mc Gee. On Food and Cooking: The Science and Lore of the Kitchen. 2004. Pages 1–896.

In addition, it has been observed, that the cooking time was increased between 200% and 1700% for the electric resistance stove with respect to the electric cooker. This increment in time is clearly related to the low power of the electric cooker, which was 500 W at the higher hob and 300 W at the smaller hob, as it is shown in Fig. 2. The energy consumption was reduced in the induction cooker between 24% and 80% with respect to the electric cooker. It was observed an increment in cost to the user by the electric stove between 24% and 80% with respect to the induction stove.

The induction stove was more efficient than the electric and LPG stoves, because induction stove reduced the cooking time and the energy consumption which contributes to minimize the cost to the user. Nevertheless, currently in Ecuador, this price of LPG is twelve times lower (MIPRO, 2015). For this reason, users have the perception that cooking with a LPG stove is less costly than cooking with an induction stove.

Fig. 2 shows the plots of the variations of active power during cooking in electric, induction and LPG stoves. Variable active power behavior during cooking in induction and LPG stoves can be seen in Fig. 2. For the induction stove it was the first time that the chefs used the stove, and for this reason some peaks appeared in the plots. In case of the electric resistance stove the power is constant for most of the cooking processes, because during the preparation of the dishes, the electric resistance stove is working most of the time close to its maximum power or the maximum power of each hob.

### *Results of CO and $CO_2$ measurements*

Fig. 3 presents the variations of CO and $CO_2$ concentrations during cooking in a LPG, induction and electric resistance stoves. In case of the electric and the induction cooker, the CO and $CO_2$ concentrations remained low, as expected. In case of the LPG cooker, the results depend on the type of dish

#### *Hard boiled eggs*

As soon as the LPG stove was turned on and the water was added (step 1 from Table 1), the concentrations of CO and $CO_2$ increased during cooking hard boiled eggs, as can be seen in Fig. 3a and b. Concentrations of CO in the idle mode reached 13 ppm which is 3 ppm (30%) higher than the acceptable value (Indoor Air Quality Standard of China (GB/T 18883), 2002; Koistinen et al., 2001; Sehjpal et al., 2014). In the working mode CO concentrations achieved a peak value of 8.5 ppm. In the idle mode concentrations of $CO_2$ reached 2200 ppm which is 1200 ppm (120%) higher than the acceptable value; meanwhile, in the working mode the concentrations achieved a peak value of 1200 ppm which is 200 ppm (20%) higher than the acceptable value.

When the egg was added (step 2 from Table 1), active power during cooking has been decreased. For this reason, concentrations of CO and $CO_2$ in the LPG stover decreased. In case of CO concentrations, they decreased under the acceptable values in idle and working mode. In case of $CO_2$ concentrations, they decreased under the acceptable values for the working mode, but $CO_2$ concentrations remained constant for the idle mode.

#### *Grilled chicken*

While cooking grilled chicken (Fig. 3c and d), the LPG stove was turned on and the oil was added (step 1 from Table 1), and the concentrations of CO in the idle mode reached 18 ppm which is 8 ppm (80%) higher than the acceptable value. In the working mode CO concentrations achieved a peak value of 13 ppm. In the idle mode concentrations of $CO_2$ reached 2000 ppm; meanwhile, in the working mode the concentrations achieved a peak value of 1200 ppm which is 200 ppm (20%) higher than the acceptable value.

**Table 4**
Information of cooking processes and the ingredients of dishes cooked in LPG electric, induction and LPG stoves.

| Dish | LPG stove | | | | | Electric resistance stove | | | | | Induction stove | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_0$ (°C) | $T_f$ (°C) | Time (s) | Energy (kW h) | [a]Price ($) | $T_0$ (°C) | $T_f$ (°C) | Time (s) | Energy (kW h) | Price ($) | $T_0$ (°C) | $T_f$ (°C) | Time (s) | Energy (kW h) | Price ($) |
| Hard-boiled egg | 15 | 94 | 1125 | 0.456 | 0.040 | 15 | 94 | 3000 | 0.298 | 0.027 | 15 | 94 | 542 | 0.169 | 0.015 |
| Grilled chicken | 15 | 72 | 510 | 0.427 | 0.038 | 15 | 72 | 1575 | 0.281 | 0.026 | 15 | 72 | 425 | 0.233 | 0.021 |
| Milk | 15 | 90 | 82 | 0.081 | 0.007 | 15 | 75.5 | 960 | 0.112 | 0.010 | 15 | 90 | 53 | 0.039 | 0.004 |
| Boiled chochos | 15 | 94 | 502 | 0.125 | 0.012 | 15 | 94 | 1419 | 0.091 | 0.009 | 15 | 94 | 210 | 0.060 | 0.006 |
| Steamed fish | 15 | 75 | 620 | 0.439 | 0.039 | 15 | 92 | 1525 | 0.250 | 0.023 | 15 | 92 | 365 | 0.214 | 0.020 |
| Boiled broccoli | 15 | 93 | 655 | 1.410 | 0.120 | 15 | 93 | 2400 | 0.140 | 0.010 | 15 | 94 | 165 | 0.065 | 0.006 |
| Little orange with oatmeal drink | 15 | 95 | 2435 | 0.690 | 0.61 | 93 | 95 | 3625 | 0.430 | 0.040 | 93 | 95 | 1205 | 0.370 | 0.034 |
| Russian salad | 15 | 94 | 8491 | 1.191 | 0.105 | 15 | 94 | 12.301 | 0.954 | 0.078 | 15 | 94 | 2406 | 0.740 | 0.068 |
| Boiled carrots | 15 | 92 | 2115 | 0.550 | 0.048 | 15 | 92 | 3058 | 0.407 | 0.037 | 15 | 92 | 595 | 0.335 | 0.031 |
| Boiled potatoes | 92 | 93 | 2416 | 0.211 | 0.019 | 92 | 93 | 3501 | 0.183 | 0.017 | 92 | 93 | 685 | 0.107 | 0.010 |
| Boiled peas | 93 | 94 | 3960 | 0.430 | 0.038 | 93 | 94 | 5692 | 0.364 | 0.034 | 93 | 94 | 1126 | 0.298 | 0.027 |

[a] For this analysis it was considered the price of a LPG cylinder of 15 kg without subsidy, $20.00.

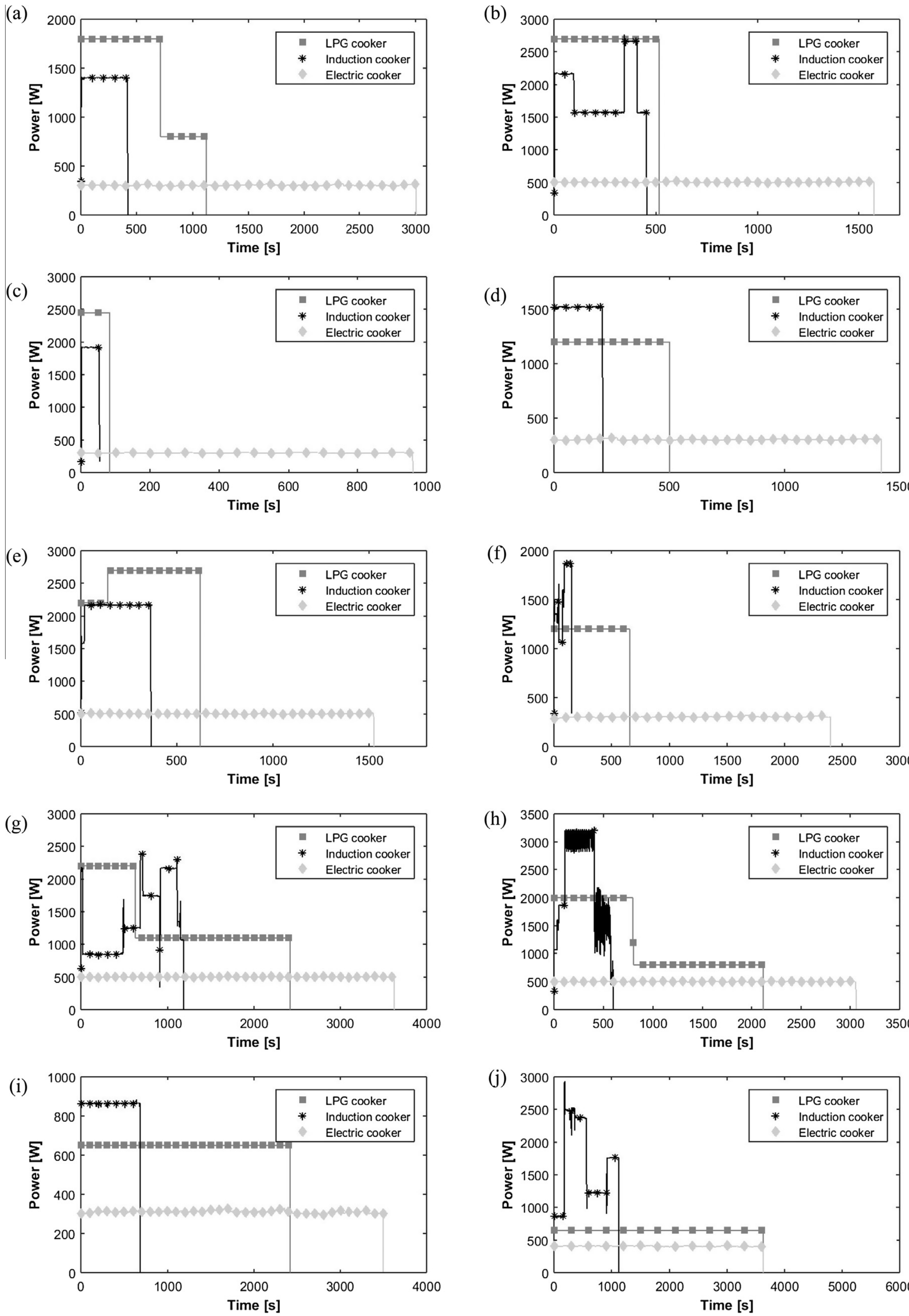



**Fig. 2.** Variations of active power during cooking in electric, induction and LPG stoves, in (a) hard boiled eggs, (b) grilled chicken, (c) milk, (d) boiled chochos, (e) steamed fish, (f) boiled broccoli, (g) little orange with oatmeal drink, (h) boiled carrots, (i) boiled potatoes and (j) boiled peas.

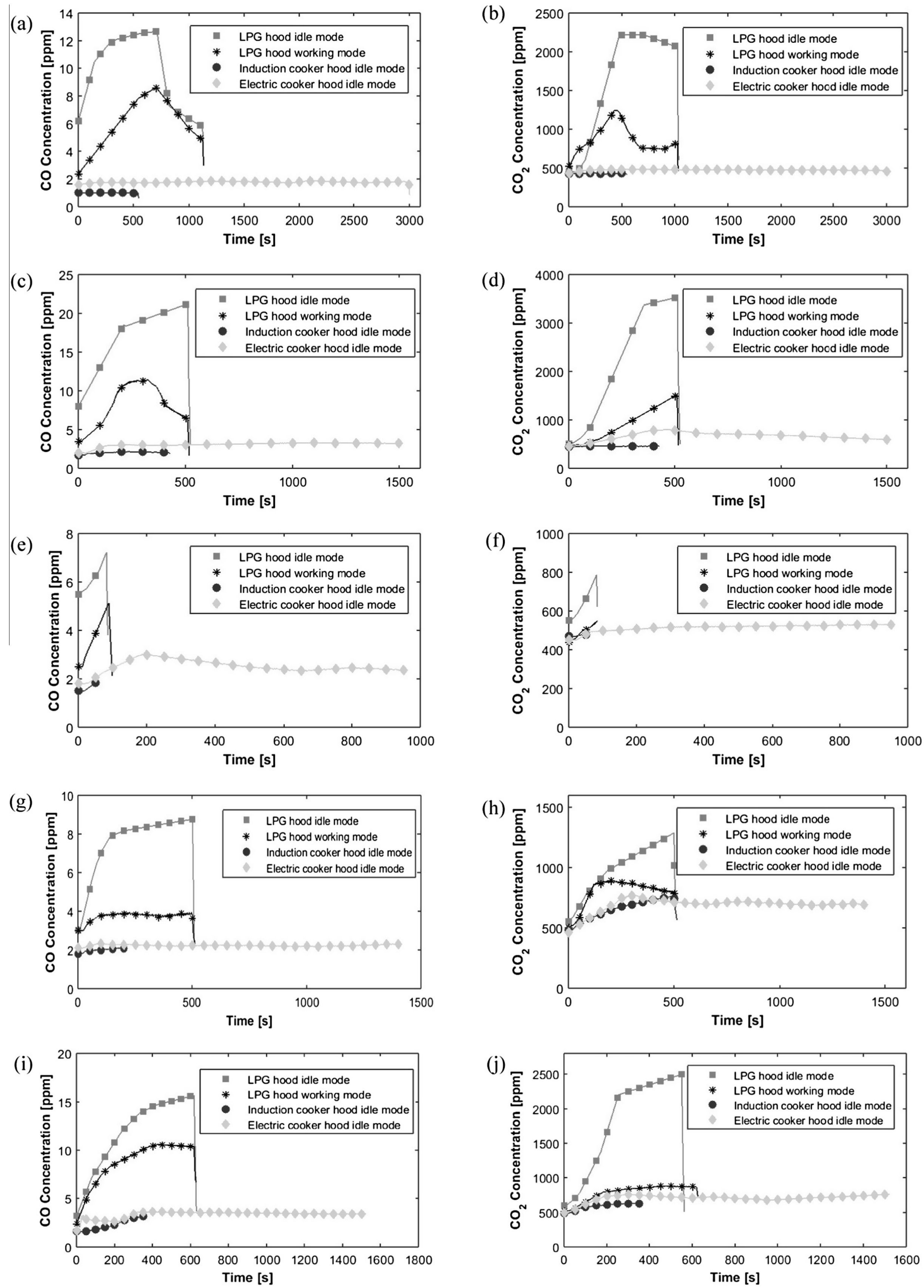



**Fig. 3.** Variations of CO concentrations and $CO_2$ concentrations during cooking in a LPG, induction and electric stoves: (a and b) hard boiled eggs, (c and d) grilled chicken, (e and f) milk, (g and h) boiled chochos, (i and j) steamed fish, (k and l) boiled broccoli, (m and n) little orange with oatmeal drink, (o and p) boiled carrots, (q and r) boiled potatoes, (s and t) boiled peas.

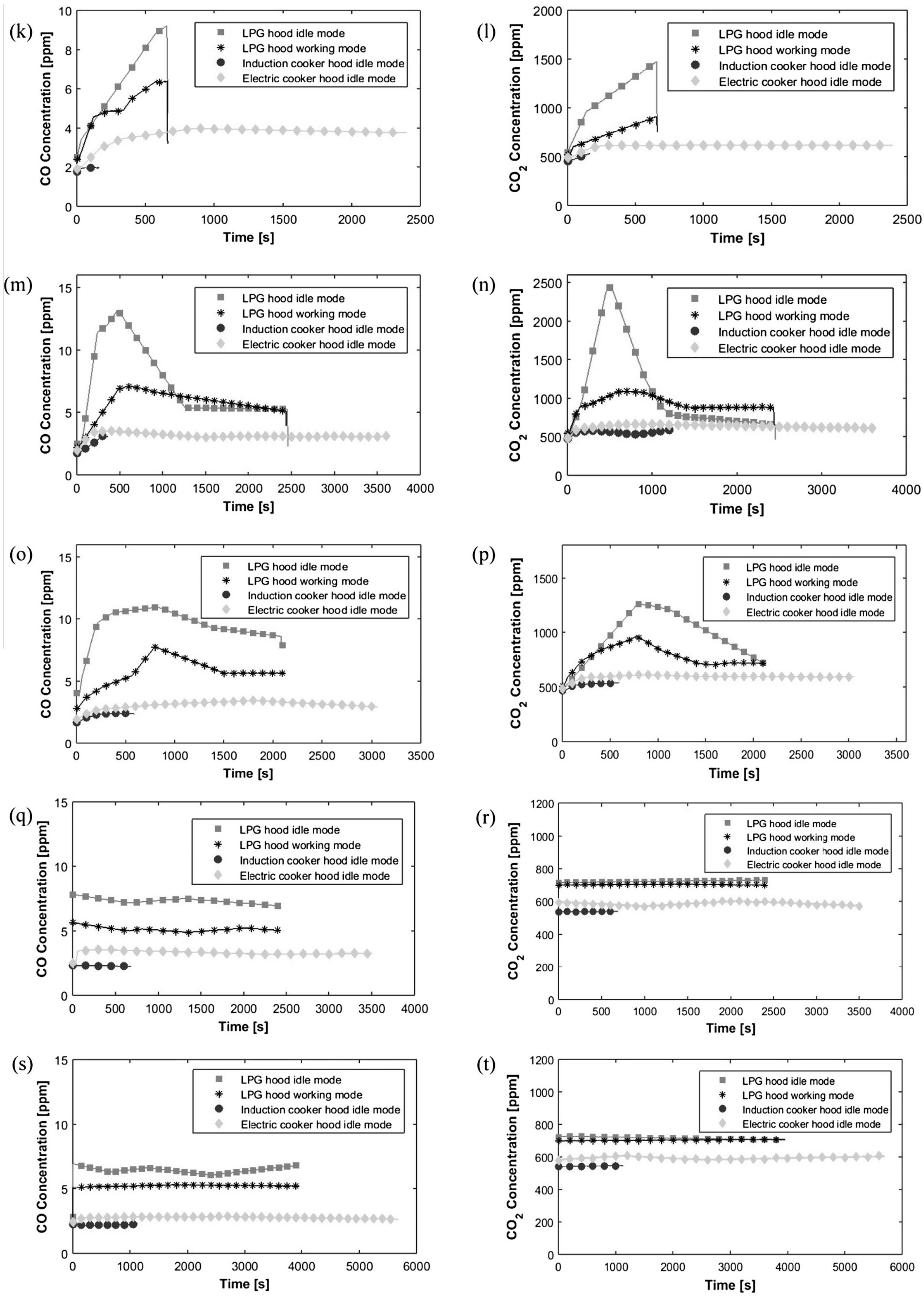



Fig. 3 (*continued*)

When the chicken was added (step 2 from Table 1), the active power during cooking has been remained constant. Concentrations of CO and $CO_2$ in the LPG stove increased in the idle mode. CO concentrations achieved a peak value of 23 ppm, which is 13 ppm (130%) higher than the acceptable value. In contrast, in working mode, they decreased under the acceptable values. In case of $CO_2$ concentrations, they reached 3600 ppm in the idle mode which is 2600 ppm (260%) higher than the acceptable value and 1600 ppm in the working mode.

*Milk*

During cooking milk the process took 83 s (Fig. 3e and f). Consequently, the concentrations of CO and $CO_2$ increased during the whole process, but they did not exceed the acceptable values.

*Boiled chochos*

When cooking boiled chochos (Fig. 3g and h), the active power remained constant during the test. So concentrations of CO increased during the test until 9 ppm. In the working mode CO concentrations increased during the test until 4 ppm. In case of the concentrations of $CO_2$, they reached 1300 ppm in the idle mode which is 300 ppm (30%) higher than the acceptable value. For the working mode $CO_2$ concentrations achieved 900 ppm.

*Steamed fish*

As soon as the LPG based cooker was turned on during cooking steamed fish (Fig. 3i and j), and the water was added (step 1 from Table 1), the concentrations of CO and $CO_2$ increased. Concentrations of CO in the idle mode reached 15 ppm which is 5 ppm (50%) higher than the acceptable value. In the working mode concentrations of CO reached a peak value of 12 ppm. In the idle mode concentrations of $CO_2$ reached 2500 ppm, which is 1500 ppm (150%) higher than the acceptable value; meanwhile, in the working mode the concentrations achieved a peak value of 850 ppm.

When the fish was added (step 2 from Table 1), the active power remained constant. In case of CO concentrations, they increased in the idle mode until 16 ppm and they decreased in the working mode until 11 ppm. In case of $CO_2$ concentrations, they increased in the idle mode until 2600 ppm and they increased in the working mode until 900 ppm.

*Boiled broccoli*

While cooking boiled broccoli (Fig. 3k and l), the active power remained constant during the test. For this reason, concentrations of CO remained within the acceptable values. During the test they reached 9.2 ppm in the idle mode and 6.8 ppm in the working mode. In case of concentrations of $CO_2$, they reached 1500 ppm in the idle mode which is 500 ppm (50%) higher than the acceptable value and 900 ppm for the working mode.

*Little orange with oatmeal drink*

While cooking the orange with oatmeal drink (Fig. 3m and n), when the cooker was turned on, the water, the oatmeal and orange were added (step 1 from Table 1). Concentrations of CO in the idle mode reached 13.2 ppm which is 3.2 ppm (32%) higher than the acceptable value. In the working mode CO concentrations achieved a peak value of 7 ppm. In the idle mode concentrations of $CO_2$ reached 2550 ppm, which is 1550 ppm (155%) higher than the acceptable value. Meanwhile, in the working mode the concentrations achieved a peak value of 1200 ppm. After 800 s of cooking, Fig. 2g shows that the active power during cooking decreased; consequently, concentrations of CO and $CO_2$ decreased until acceptable values.

*Boiled carrots*

As soon as the cooker was turned on during cooking of the boiled carrots (Fig. 3o and p), when the water with carrots was added (step 1 from Table 1), the concentrations of CO and $CO_2$ increased. Concentrations of CO in the idle mode reached 11 ppm which is 1 ppm (10%) higher than the acceptable value. However, in the working mode CO concentrations achieved a peak value of 8 ppm.

In the idle mode concentrations of $CO_2$ reached 1350 ppm, which is 350 ppm (35%) higher than the acceptable value; meanwhile, in the working mode the concentrations achieved a peak value of 900 ppm.

Fig. 2h shows that after 800 s of cooking the active power decreases. For this reason, concentrations of CO and $CO_2$ decreased until acceptable values.

*Boiled potatoes*

During cooking boiled potatoes (Fig. 3q and r), the active power remained at 850 W in the LPG stove during the test. For this reason, concentrations of CO have been remained into the acceptable values. During the test they reached 8 ppm in the idle mode and 5.6 ppm in the working mode. In case of concentrations of $CO_2$, they reached 770 ppm for the idle mode and 75 ppm for the working mode.

*Boiled peas*

While cooking the boiled peas (Fig. 3s and t), the active power remained at 675 W during the test. Consequently, concentrations of CO remained within the acceptable values. During the test they reached 7 ppm in the idle mode and 5 ppm in the working mode. In case of concentrations of $CO_2$, they reached 720 ppm for the idle mode and 700 ppm for the working mode.

*Results of the organoleptic measurement*

The results of the sensory evaluation are shown in Table 5. A total of one hundred and seven panelists participated in the taste, they determined a significantly difference ($\alpha = 0.001$) in little orange with oatmeal, grilled chicken, steamed fish and broccoli and it was not perceptible in Russian salad, which were cooked with the same methodology in induction and LPG stoves. The degree of difference in these four dishes was moderate. Three of the four dishes cooked with induction cooker were more acceptable than that one's cooked with the LPG stove ($\alpha = 0.05$). In the other dish appeared equally acceptable when cooked in the induction stove and in the LPG based stove.

**Table 5**
Results of sensory evaluation: triangular, degree of difference and acceptance tests.

| Food | Correct answers in triangular test | Degree of difference test | Acceptance test |
|---|---|---|---|
| Russian salad | 5/17 | Non perceptible | Two processes are accepted. Induction and LPG stoves |
| Orange with oatmeal drink | 18/25 | Moderate | Induction stove |
| Grilled chicken | 16/25 | Moderate | Induction stove |
| Steamed fish | 13/21 | Moderate | Two processes are accepted. Induction and LPG stoves |
| Broccoli | 15/21 | Moderate | Induction cooker |

*Results of physicochemical and microbiological measurements*

Table 6 shows the results that are outside the range, obtained before and after the thermal treatment. The used references were found in national standards, books and nutrition fact tables of the macronutrients containing in food as Table 7 shows (Hernandez, 2010; INEN, 2010, 2012, 2013, 2014; Reyes et al., 1997; Valls et al., 1999; Verdú, 2013) except for Russian salad and the little orange with oatmeal drink. Only milk and chochos references had concentration ranges. For milk, hard-boiled eggs and boiled broccoli a comparative range of ±10% of the reference value was defined.

The microbiological and physicochemical changes produced by thermal treatment in food are described in Tables 7 and 8. The analyzed micronutrients were vitamin C in broccoli and vitamin A in egg, broccoli and Russian salad. Both of them present moderate sensitivity to heat (Martínez et al., 2005). After the thermal treatment, it was observed that vitamin C lost in similar quantities in the three types of cookware, while vitamin A lost in less quantity when using the induction cooker. The vitamin A keep was incremented by induction stove between 160% and 471% more than the LPG stove and between 41% and 546% more than the electric stove.

In order to evaluate the microbiological load, national standards were used, as shown in Table 7. Only for the milk and the fish, requirements for before and after the thermal treatment were found. The milk and the chicken, as feedstock, are above the allowed concentrations during total recount of bacteria. After the thermal treatment the total bacteria concentration in the boiled milk in the LPG stove does not meet the requirements, and the other samples of microbiological load of spoilage and pathogenic decrease to concentrations that are not harmful for human health.

## Discussion

Different from several former researchers (Li et al., 2012; Zhao et al., 2014) and same than other studies (Chao et al., 1996; Chiang et al., 2000), we found the cooking techniques in an LPG stove, like boiling or frying is the one to blame to increase the emissions of CO and $CO_2$. Furthermore, the tests showed how the frying process increased the concentrations of CO and $CO_2$. The emissions of CO and $CO_2$ not only were related to the cooking time, but also occurred largely as a result of the burning of the LPG. Consequently, the higher calorific power used in the LPG stove during cooking, the larger of $CO_2$ was generated. When the frying oil was added into the dish, the maximum emissions of CO and $CO_2$ during cooking this kind of dishes is at least 138% higher than the others in CO emissions and 135% higher than the others in $CO_2$ emissions, in case of the idle mode at the hood. For this reason, it is necessary to seek more effective solutions like the working mode of the hood, or other. A LPG stove increases the concentrations of CO and $CO_2$ during the preparation of the food. Indeed, they exceed the maximum levels of volatile emissions acceptable into buildings (Indoor Air Quality Standard of China (GB/T 18883), 2002; Koistinen et al., 2001; Sehjpal et al., 2014). On the other hand, electrical and induction stoves kept the concentrations within the acceptable levels. Moreover, it was observed that the induction stove improves user quality of life. It has been observed that the production of carbon dioxide and carbon monoxide decreases indoors and for this reason it could be sold a cleaner technology.

The values of test parameters finally reached a stable value after a certain period of time. It should be noted that many families in Ecuador do not have an exhaust hood. Consequently, the emissions of CO and $CO_2$ during cooking would be higher.

The results of the cooking process, which has considered the cooking habits of the Ecuadorian cuisine, concludes that induction stoves decreased the energy cost between 24% and 80%, when it is compared with electric stove. This increment in of the electric cooker with respect of the induction cooker time is clearly related to the low power of the electric cooker, which was 500 W at its peak when is working the higher hob. In case of the LPG based cooker the energy cost was increased between 41% and 167%, when it is compared with induction stoves, considering a price for the 15 kg LPG cylinder of $20.00, which is the price in neighbors' countries of Ecuador. In contrast, currently in Ecuador, this price is twelve times lower and users have the misconception that cooking with a LPG stoves is cheaper than cooking with an induction cooker. For the electric cooker, the energy consumption was reduced by the induction cooker with respect to the electric cooker.

The temperature and cooking time of food are influenced by the atmospheric pressure that is inversely proportional to the height above sea level (Price, 1996). Therefore, the results of this study are specific for highlands. All kinds of food have water in its chemical composition and are mostly cooked in aqueous media. Finishing cooking in highlands takes longer than in other cities due to the heat at thermal treatment is reached at less temperature. With these conditions, volatile organic compounds contained in food are easy to escape, even before the thermal treatment and have a direct influence with the flavor lost (Price, 1996), which represent the complex set of olfactory and taste properties perceived during tasting (Valls et al., 1999).

The organoleptic test was performed without experienced judges because INER researchers do not have a tasting training. However, for this test it was enough for the panelists to be usual consumers and to be familiar with the five dishes. This fact increased the likelihood of finding a significant difference in the samples (Standard ISO BS 4120, 2004).

The Russian salad and the little orange with oatmeal drink were the dishes more complex because in both of them several elements are mixed. The Russian salad is a solid–solid mixture and the little orange with oatmeal drink is a solid–liquid mixture. These dishes were cooked and presented as homogeneously as possible. Between the five evaluated dishes, only the Russian salad did not present a significant difference in the discriminative triangular test. Usually, the solid mixtures are less homogeneous. It is because of this principle that no difference was detected in the Russian salad samples. On the other hand, the affective test shows that food cooked in induction cooker present a higher acceptance in the consumers, except for the steamed fish. In this research, the panelists

**Table 6**
Macronutrients outside the reference range. F: feedstock; I: induction; L: LPG; E: electric.

| | Protein | Humidity | Fat | Ash Ceniza | Fiber | Carbohydrates |
|---|---|---|---|---|---|---|
| Milk (Hernandez, 2010; INEN, 2012) | F, I, L, E | | | I | | F |
| Chochos (INEN, 2014) | F, I, L, E | F | E | | F, I, L, E | F, I, L, E |
| Egg (Reyes et al., 1997) | | | F, I, E | F, I, L | | F |
| Broccoli (Reyes et al., 1997) | F, I, L, E | | F, I, L, E | F, I, L, E | F, I, L, E | F, I, L, E |
| Grilled chicken (INEN, 2010; Reyes et al., 1997) | | | I, L | | | |

**Table 7**
Microbiological and physiochemical changes produced by thermal treatment in food (Labor, 2004; Yepiz-Gomez et al., 2006; INEN, 2010, 2013, 2014; Valls et al., 1999; Verdú, 2013).

| | Global chemistry composition (Yepiz-Gomez et al., 2006) | Pasteurized (Labor, 2004) | Feedstock | Induction | Electric | LPG |
|---|---|---|---|---|---|---|
| *Milk* | | | | | | |
| Total bacterial count (UFC/ml) | 1.5E+06 (maximum) | 3.0E+04 (maximum) | 1.3E+08 | 3.7E+02 | 7.7E+02 | 1.5E+05 |
| Total coliform count (UFC/ml) | | <1 | 7.1E+05 | <10 | <10 | <10 |
| Mold count (UFC/ml) | | | <10 | <10 | <10 | <10 |
| Leaven count (UFC/ml) | | | 3.4E+04 | <10 | <10 | <10 |
| *E. coli* count (UFC/ml) | | <10 UFC/g | <10 | <10 | <10 | <10 |
| *S. aureus* count (UFC/ml) | | | 3.7E+02 | <10 | <10 | <10 |
| *Salmonella* spp. (Detection/ 25 ml) | | Absence/25 g | Absence | Absence | Absence | Absence |
| Protein (%) | 2.9–4 | 2.9 minimum | 2.58 | 2.59 | 2.89 | 2.41 |
| Humidity (%) | 85–90 | | 89.23 | 88.59 | 88.53 | 88.77 |
| Fat (%) | 2.5–5 | 3 (minimum) | 3.5 | 3.46 | 3.53 | 3.47 |
| Ash (%) | 0.7–1 | 0.65–0.80% | 0.78 | 0.60 | 0.67 | 0.68 |
| Carbohydrates (%) | 4–5.5 | | 3.91 | 4.76 | 4.38 | 4.67 |
| | Boiled with skin (INEN, 2014) | Debittering (Verdú, 2013) | Feedstock | Induction | Electric | LPG |
| *Boiled chochos* | | | | | | |
| Total bacterial count (UFC/g) | | 18.0E+02–1.0E+03 | 1.0E+07 | <10 | 1.0E+01 | 3.0E+01 |
| Total coliform count (UFC/g) | | 10–10.0E+02 NMP/g | 1.2E+05 | <10 | <10 | <10 |
| Mold count (UFC/g) | | 0–5E+02 | <10 | <10 | <10 | <10 |
| Leaven count (UFC/g) | | | 5.0E+03 | <10 | <10 | <10 |
| *E. coli* count (UFC/g) | | Absence | <10 | <10 | <10 | <10 |
| Protein (%) | 11.6 | 12.5–13 | 16.02 | 13.09 | 12.54 | 15.77 |
| Humidity (%) | 69.7 | 72–75 | 71.19 | 72.61 | 71.83 | 71.95 |
| Fat (%) | 8.6 | 4.7–6.0 | 5.67 | 5.78 | 4.39 | 5.32 |
| Ash (%) | 0.6 | 0.5–0.8 | 0.59 | 0.66 | 0.67 | 0.63 |
| Crude fiber (%) | 5.3 | 1.8–2.3 | 6.53 | 7.86 | 10.56 | 6.33 |
| Carbohydrates (%) | 9.5 | 3–8.5 | 0 | 0 | 0.01 | 0 |
| | Fresh, refrigerated, frozen (INEN, 2013; Valls et al., 1999) | Pasteurized or boiled | Feedstock | Induction | Electric | LPG |
| *Steamed fish* | | | | | | |
| Total bacterial count (UFC/g) | 5.0E+05 maximum | | 2.0E+05 | <10 | <10 | <10 |
| Total coliform count (UFC/g) | | | 1.0E+02 | <10 | <10 | <10 |
| *E. coli* count (UFC/g) | 10 maximum | <10 | <10 | <10 | <10 | <10 |
| *S. aureus* count (UFC/g) | 100 maximum | | <10 | <10 | <10 | <10 |
| *Salmonella* spp.(Detection/ 25 g) | Absence | Absence | Absence | Absence | Absence | Absence |
| Protein (%) | 19.5 | | | 27.68 | | 29.01 |
| Humidity (%) | 72.9 | | | 70.55 | | 69.09 |
| Fat (%) | 4.5 | | | 0.68 | | 0.78 |
| Ash (%) | 1.4 | | | 1.09 | | 1.12 |
| | From chicken (INEN, 2010) | From chicken, hard-boiled egg (INEN, 2010) | Feedstock | Induction | Electric | LPG |
| *Hard-boiled egg* | | | | | | |
| Protein (%) | 13.5 | 12.9 | 14.5 | 14.17 | 13.36 | 12.59 |
| Humidity (%) | 75.4 | 75.9 | 72.13 | 71.92 | 72.21 | 73.14 |
| Fat (%) | 8.4 | 8.4 | 10.79 | 10.18 | 10.09 | 9.06 |
| Ash (%) | 0.9 | 0.9 | 1.04 | 1.13 | 0.94 | 0.78 |
| Carbohydrates (%) | 1.8 | 1.9 | 1.54 | 2.6 | 3.4 | 4.43 |
| Vitamin A (UI/100 g) | | | 1085.73 | 992.17 | 153.5 | 223.62 |
| | Consumable part (INEN, 2014) | | Feedstock | Induction | Electric | LPG |
| *Broccoli* | | | | | | |
| Protein (%) | 4.9 | | 2.5 | 2.9 | 2.75 | 3.15 |
| Humidity (%) | 87.3 | | 86.27 | 85.75 | 85.74 | 86.59 |
| Fat (%) | 0.9 | | 0.51 | 0.64 | 0.63 | 0.44 |
| Ash (%) | 1.2 | | 0.84 | 0.6 | 0.53 | 0.65 |
| Crude fiber (%) | 1.6 | | 9.88 | 9.99 | 10.1 | 9.07 |
| Carbohydrates (%) | 5.7 | | 0 | 0.12 | 0.25 | 0.1 |
| Vitamin A (UI/100 g) | | | 834.09 | 465.99 | 328.51 | 178.68 |
| *Vitamin C (mg/100 g) | | | 83.2 | 22.56 | 25.25 | 21.43 |

(*continued on next page*)

**Table 7** (*continued*)

| | Meat pulp (Yepiz-Gomez et al., 2006; INEN, 2010) | Feedstock | Induction | Electric | LPG |
|---|---|---|---|---|---|
| *Grilled chicken* | | | | | |
| Total bacterial count (UFC/g) | 18.0E+02–1.0E+03 | 1.1E+05 | <10 | <10 | <10 |
| Total coliform count (UFC/g) | | 6.9E+04 | <10 | <10 | <10 |
| *E. coli* count (UFC/g) | 1.0E+02–1.0E+03 | <10 | <10 | <10 | <10 |
| *S. aureus* count (UFC/g) | 1.0E+02–5.0E+02 | <10 | <10 | <10 | <10 |
| *Salmonella* spp./(Detection/ 25 g) | Absence | Absence | Absence | Absence | Absence |
| Protein (%) | 21.4 | | 28.06 | | 28.94 |
| Humidity (%) | 75.5 | | 66.99 | | 66.86 |
| Fat (%) | 3.1 | | 2.79 | | 2.84 |
| Ash (%) | 1.0 | | 2.16 | | 1.36 |
| | Feedstock | | Induction | Electric | LPG |
| *Russian salad* | | | | | |
| Total bacterial count (UFC/g) | 3.6E+06 | | <10 | <10 | <10 |
| Total coliform count (UFC/g) | 1.0E+04 | | <10 | <10 | <10 |
| Mold count (UFC/g) | <10 | | <10 | <10 | <10 |
| Leaven count (UFC/g) | 4.2E+02 | | <10 | <10 | <10 |
| *E. coli* count (UFC/g) | <10 | | <10 | <10 | <10 |
| Protein (%) | 3.17 | | 1.92 | 1.74 | 2.26 |
| Humidity (%) | 73.11 | | 78.9 | 72.81 | 71.11 |
| Fat (%) | 0.51 | | 0.59 | 0.59 | 0.56 |
| Ash (%) | 0.83 | | 0.35 | 0.47 | 0.51 |
| Crude fiber (%) | 5.56 | | 5.75 | 5.08 | 5.25 |
| Carbohydrates (%) | 16.82 | | 12.94 | 19.31 | 20.31 |
| Vitamin A (UI/100 g) | 1124.59 | | 927.91 | 206.15 | 162.74 |
| | Orange | Oatmeal | Induction | Electric | LPG |
| *Little orange with oatmeal drink* | | | | | |
| Total bacterial count (UFC/g; UFC/ml) | | 1.0E+02 | <10 | <10 | <10 |
| Total coliform count (UFC/g; UFC/ml) | | <10 | <10 | <10 | <10 |
| Mold count (UFC/g; UFC/ml) | 1.0E+02 | <10 | <10 | <10 | <10 |
| Leaven count (UFC/g; UFC/ml) | 8.7E+06 | 10 | <10 | <10 | <10 |
| *E. coli* count (UFC/ml) | | | <10 | <10 | <10 |
| Protein (%) | | | 0.38 | 0.46 | 0.43 |
| Humidity (%) | | | 91.73 | 92.4 | 91.22 |
| Fat (%) | | | 0.35 | 0.41 | 0.35 |
| Ash (%) | | | 0.08 | 0.25 | 0.17 |
| Crude fiber (%) | | | 0.68 | 0.79 | 0.67 |
| Carbohydrates (%) | | | 6.78 | 5.69 | 7.16 |

**Table 8**
Chemical and physical changes produced by thermal treatment in food (Hernandez, 2010; Martínez et al., 2005; Labor, 2004).

| Physical | Chemical | |
|---|---|---|
| Volume | Nutrient | Effect |
| Color | Proteins | • Coagulation of colloidal solutions (70–80 °C)<br>• Protein hydrolysis and breakdown of muscle fibers when excessive heating<br>• Denaturation but not casein coagulation (in milk)<br>• Enzymes inactivation<br>• Digestibility improvement (<100 °C) |
| Consistency | Lipids | • Foundry and partial abandonment<br>• Formation of acrolein (>180 °C), a substance with unpleasant taste |
| Organoleptic characteristics | Carbohydrates | • Solubilization<br>• Gelatinization of complex carbohydrates in a moist environment (60–70 °C)<br>• Dextrinization, change of color and flavor in dry environment<br>• Carbonization (>170 °C) |
| | Vitamins | • Solubilization<br>• Oxidation |
| | Minerals | • Solubilization |

are able to detect difference and accept the food cooked in both cookers. This sensory test indirectly measures the induction cookers acceptance.

The nutritional quality of any kind of food depends on the thermal treatment used. The usual chemical and physical changes are presented in Table 8. The energy intake does not get affected because the macronutrients are lost in a lower quantity. Generally, vitamins and minerals vanish. These food components do not supply energy to human body, but they are essential in every chemical reaction that produces energy (Yepiz-Gomez et al., 2006). The chemical composition of any kind of food can be modified for changes in weather conditions, soil type (in vegetables) and feeding type (in animals). A change in these conditions could have modified the chemical composition of analyzed food. It is for this reason that some products are outside the reference range.

On the other hand, the thermal treatment used in the three stoves decreased the microbiological load to the acceptable levels, except for milk boiled in the LPG stove, where the total bacterial count is higher than the quality requirement established in the standard NTE INEN 10:2012 (INEN, 2012). There was likely a contamination during sampling and/or analysis, which might have changed was determinant to modify the results. Despite having different cooking times, the three kinds of cookers guarantee the food safety as shown in Table 7.

## Conclusions

The results of the cooking process information, conclude that in the LPG stove the time, energy consumption, and cost were higher with respect to the induction stove. The time reduction is related to the heating processes of water or oil. The reduction in energy consumption and cost is related to the higher energy efficiency of the induction stove. In the electric stove the cooking time, energy consumption, and cost were higher with respect to the induction stove. The increment in time is related to the low power of the electric stove, and the energy consumption and cost are due to the energy efficiency of the stove.

The results concluded that during cooking the case study of the dishes of eight cuisines of Ecuador, concentration of CO and $CO_2$, increased during the entire process. In the whole process, it has been observed that the in LPG based stove, the concentrations of CO and $CO_2$ in hood idle mode and working mode have been increased over the acceptable values. Furthermore, it can be seen that the maximum values of the contaminants appear during grilled chicken with achiote oil in the hood idle mode. In contrast electric and induction stoves keep low CO and $CO_2$ concentration, as expected and they do not exceed the acceptable values.

Food flavor does not change; it is lost due to the height above sea level, temperature and cooking time. In Quito, the panelists detected the difference between food cooked in induction stove and LPG based stove. The degree of difference is moderate (comparing it with the same dishes cooked in the LPG based cooker); besides, food cooked in induction cookers presents more acceptance.

The microbiological analysis showed that the pathogens and spoilage present in the food cooked in the three types of stoves are reduced to concentrations no harmful to human health. The vitamin A lost in less quantity in food cooked in induction stove than electric and LPG stoves, while vitamin C lost in similar quantities when cooking in any of the stoves. The chemical composition of some food (feedstock and finished product) is outside the reference range described in standards, books and nutrition facts tables (Hernandez, 2010; INEN, 2010, 2012, 2013, 2014; Reyes et al., 1997; Valls et al., 1999; Verdú, 2013).

The study concluded that the positive aspects in induction cookers are as follows: (i) efficiency in cooking time, energy consumption and cost, (ii) no emission of harmful concentrations of CO and $CO_2$, (iii) the food cooked is more acceptable, (iv) less quantity of vitamin A losses, and (v) high food safety.

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