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THERMAL ENERGY RATIONALISATION AND ENVIRONMENTAL POLLUTION REDUCTION FOR BALADY BREAD BAKERIES

Abou El-Magd, A.E; E. A. Amin and A.H. Jado
Agric. Eng. Dept., Fact. Agric., Mansoura Univ.

ABSTRACT

The thermal energy efficiency, the specific energy consumption, and the emission of exhaust gasses of three different balady bread ovens were investigated, and evaluated. The compared ovens are installed in three different balady bread bakeries namely: - Full-mechanical automatic using solar fuel (MA-L); Semi -mechanical automatic using natural gas fuel (SMA-G); and Semi -mechanical automatic using solar fuel (SMA-L). The comparative tests were deduced under numerous variables included the fuel type, volumetric air/fuel ratio (A/F), and the baking capacity.

The obtained results revealed that, the optimum oven thermal efficiency (88.56%) in (SMA-G) bakery was obtained at A/F ratio of 12.24 and flue gases temperature of 276.66° C. While, optimum thermal efficiencies of 85.54 % in (SMA-L) bakery, and 86.61% in (M-L) bakery were obtained at similar A/F ratio of 19.76, and at flue gas temperatures of 326,and 304° C respectively.

The results also indicated that the least specific fuel energy consumption value (2.03 MJ/ kg flour) was corresponded the (SM-G) bakery. While the highest value (5.38 MJ/ /kg flour) was corresponded the (SM-L) bakery.

The results of exhaust gas emission showed that, the emission of sulfur dioxide (SO_2) and nitrogen monoxide (N_2O) were higher in case of operating SMA-L bakery than those of operating MA-Land SMA-G by about 2.09 and 5.85 times respectively. In addition replacing the natural gas instead of solar as a fuel resulted in high reduction the environmental pollution produced from the balady bread bakeries under the Egyptian conditions. Whereas, the emissions of toxic compounds (such as benzene, toluene, xylene, and trichloroethylene (TCE)) weren't detected in case of using natural gas, while, these compounds were 71-9-12-18 and 88-16-18-23 ppm for (MA-L, SMA-L) oven respectively that used solar fuel.

INTRODUCTION

Energy considers important vital resource for food industries. Petroleum represents the most important source of energy supply in Egypt.Egypt consumed 2.83 million ton of petroleum in food industries, which represent about 22% of total energy consumed in industry (Ahmed 1992).

Egyptian balady bread is a very popular type of bread in the Egyptian market. During the last two decades, the rapid growth of population resulted in an increase demand of this type of bread . There for , mechanization of bread baking process was the most important dominant target. There are over 21,000 mechanized balady bread bakeries in Egypt[1]spread throughout the country, these bakaries produce vast amount of bread and have a wide variation in designs, construction materials, burner type and fuel type.

([1]) source : Ministry of Supply & Home Trade

Gadalla, *et.al*. (1995) indicated that balady bread is produced as soft (130 g / loaf at 36% humidity) and hard [(can be called well - baked low moisture high quality bread (110 g / loaf at 26%humidity).

Fellows (1990) showed that, in the direct heationg ovens, air and products of combustion are recalculated by natural convection or by fans. The temperature in the oven is controlled automatically, by adjustment of air and fuel flow rates to the burners. He stated also that gas (as a commonly used fuel) is burned in ribbon burners located above and below conveyor belts in continuous ovens.

Alain Le-bail *et. al*. (2010) indicated that Bread baking is one of the most energy demanding processes (around 4 MJ/kg), compared with other thermal processes such as canning.

Bennion (1970) indicated that combustion is the process involved in burning fuels is generally carried out in air and depends not only on the fuel consumed but essentially upon a chemical action between the fuel and some other substance which is usually air. The combustion or burning of the most common fuels involves the reaction of carbon and hydrogen in the fuels with oxygen in the air to produce carbon dioxide and water vapor. He also indicated that the air-fuel ratio represents the theoretical volume of air which is necessary for the complete combustion of 1 m^3 of fuel under standard condition (0 °C and 1 atm).

EL-kady (2002) explained the factors affecting thermal efficiency as the excess air rate, burner performance, firing rate flue gas temperature, and combustion air temperature. He also reported that the excessive reduction in flue gases temperature is also not recommended, as it is known that flue gases temperature should not be reduced below its dew point temperature (275 ° C) that results corrosion problems due to acid formation.

Reed (1983) reported that fuel oil must be atomized by compressed air and suitable burners. It is very important to obtain the complete atomization and mixing of the air and fuel in order to obtain the smokeless flame which indicates maximum efficiency. In oil fuel burner a blower must be installed to supply air to the burner under pressure that atomizes the oil fuel as it enters the burner and forms a complete mixture. this mixture of oil and air - in a fine spray- is then ignited at the nozzle.

FDF (2008) identified that the heat loss of flue gases emitted during baking represents 82% of total losses and the radiation loss depends upon the design and the insulation of bakeries. In general, it is between 0.5 and 3%.They also reported that the excess air value must be kept low, as it needs to be heated resulting in a decrease of the flame temperature and an increase of the flue gas temperature, thereby deteriorating the efficiency.

Anon (2005) reported that the guide values for CO (1.25 mg/m^3),SO_2 (0.1144 mg/m^3) and N_2O (0.1845 mg/m^3).

In Egypt, there is a few numbers of studies that focused on the thermal efficiency of the ovens and polluted gases emitted outside the ovens during baking of balady bread.

The aim of the present study is to rationalise fuel energy, and reduce the emissions of polluted gases during baking balady bread loaves in Egypt. Therefore, the objectives of the present study are devoted to determine the specific energy consumption, the thermal energy efficiency, and the concentrations of emitted gases outside three different balady bread ovens.

MATERIALS AND METHODS

Materials:

The three investigated bakeries are varied in designs, construction materials, fuel type, burner type, productivity and number of baking chamber. These variations may be illustrated as follows:-

Mechanical automatic bakery using light fuel oil (MA-L)

The first investigated bakery has a single continuous running conveyor belt oven. It was installed at Met-Elkholy Abdela-Damietta. This bakery will be referred in the present study as (MA-L) . The oven of that bakery was constructed of fireclay brick and traditional red brick and contains one direct-heated baking chamber with one continuous running baking conveyor belt . The belt was made of steel plates and steel conveyor chains with dimensions of 450x75 cm for producing soft baked balady bread. The oven combustion system includes one light fuel oil automatic burner which consists of a fuel pipe with a nozzle inserted in the outlet pipe of an air blower, The light fuel oil composition as recommended by Ministry of supply&Home trade was 86% C, 13% H and 1% S. The average oven productivity was 4000.4 ± 2.1747 loaves / hr.

Semi -Mechanical automatic bakery using light fuel oil (MA-L)

The second investigated bakery was a single continuous running conveyor belt oven. It was installed at Met-Elkholy Abdela-Damietta. This bakery will be referred in the present study as (SMA-L). The oven was contains of two direct-heated baking chamber . The oven construction and the conveyor dimension that used in (SMA-L) bakery where similar to that unit used in (MA-L) bakery. Also the fuel type and it is combustion was also similar to that used in (MA-L) bakery. The oven combustion system includes two light fuel oil manually controlled simple burner consists of a fuel pipe with a nozzle inserted in the outlet pipe of an air blower. The average oven productivity is 2351.867 ± 1.8085 loaves / hr.

Semi -Mechanical automatic bakery using natural gas fuel (SMA-G)

The third investigated bakery was a single continuous running conveyor belt oven installed at faculty of agriculture at Mansoura university**.** This bakery will referred in the present study as (SMA-G) The oven contains two direct- heated baking chamber constructed mainly of medium - duty straight fireclay brick of 30% alumina content and super-duty straight and side arches fireclay brick of 42% alumina content for the inner walls and arch, while the outer walls were built using traditional red brick. The inner brick construction is covered with flat thermal insulated steel sheetiron covers. The oven has a steel frame and steel angle bars work as guides for the conveyor belts chains. steel conveyor chains with dimensions of 450x75 cm. The combustion system includes one natural gas automatic burners The average oven productivity was approximately 2501.067 ± 1.7687 loaves / hr.

The main specifications of the three tested ovens are summarized in table (1).

Table (1): The specifications of the three tested ovens.

Specifications	Oven Symbol		
	MA-L	SMA-L	SMA-G
Construction materials of oven	Fiercely Brick	Fiercely Brick	Fiercely Brick
Fuel type	Light fuel Oil	Light fuel Oil	Natural Gas
Average Productivity (loaves/hr)	4000.4 ± 2.1747	2351.867 ± 1.8085	2501.067 ± 1.7687
Number of baking chambers	One	Two	Two

Table (2) : solar fuel properties used in ovens.

Heating value	54,600 kJ/litre
Specific weight	0.82 - 0.89 g/cm^3
Sulfur content	0.5%
Air : Fuel ratio	15.2 Kg air/Kg fuel

[Reference Ministry of Supply & Home Trade.]

Table (3) : Natural gas properties.

Heating value	39,000 kJ/m^3
Specific weight	0.57 – 0.75 g/cm^3
Sulfur content	1.5%
Air : Fuel ratio	10.2 m3 air/m3fuel

[Reference: Natural gas project Co.]

Test instrument:

Combustion gas analyser

The used gas analyser shown in fig. (1) used to measures and calculates the concentrations of $CO_2$and O_2 for the combustion flue gases of different types of fuel (light fuel oil and natural gas).The apparatus also measures both of the flue gases temperature (Tf_g) and the ambient temperature (T_A) where it is equipped with a flue gas probe with Chromel-Alumel (type K) thermocouple. The apparatus also has the ability to calculate the excess air rate and the thermal efficiency (Et_a) of the ovens .

Fig. (1): combustion gas analyzer

Portable Ambient Air Analyzer:

The analyser shown in fig. (2) was used after determination of the optimum thermal efficiency to measure the emitted gases outside bakeries during baking .

Fig. (2): portable Ambient Air Analyzer

METHODS:

Concentration of the flue gases,excess air rate and thermal efficiency of the ovens :

The concentrations of $C0_2$and O_2 for the combustion flue gases of the different types of fuel (light fuel oil and natural gas) , the excess air rate and the thermal efficiency of the ovens (Et_a) were measured using the combustion gas analyzer using the following methods:

Excess air:

In reality it is not possible to achieve a perfect combustion using the theoretically required amount of air. Therefore excess air is needed.

The ratio of the volume of air to the volume of air theoretically required is excess air.

$$\text{Lambda} = 20.9 / (20.9 - O_2\text{meas.})$$

The excess air value must be kept low, as it needs to be heated resulting in a decrease of the flame temperature and an increase of the flue gas temperature, thereby deteriorating the efficiency.

Carbon dioxide CO_2:

The CO_2 percentage in flue gases depends upon the amount of carbon contained in the fuel.

In order to achieve an optimum combustion a small CO value and a maximum CO_2 value must be set (ideally the entire carbon is converted into CO2).

$$CO_2 = CO_2\ \text{max.} \times ((20.9 - O_2\ \text{meas.}) / 20.9)$$

CO2max = max. CO_2 of the fuel

The flue gas CO content that results from incomplete combustion is to be kept as small as possible because of its toxicity. In addition this CO content takes up latent heat, which results in higher flue gas losses.

Heat Losses:

Complete utilization of heat emitted during the combustion process is desirable, as is a very small heat loss of flue gases. The loss of free heat is caused by the temperature difference between the fuel air mixture entering the furnace and gases evolved. The larger the amount of excess air and thereby the volume of flue gas and the higher the flue gas temperature the higher the losses and smaller the thermal efficiency of the bakeries. The heat losses can be calculated by the equation below:

$$q_A = (T_{FG} - T_A) * \left(\frac{A_2}{20.9 - O_2} + B \right) (\%)$$

Where:

$q_A =$ Losses in %

$T_{FG} =$ Flue gas temperature in c

$T_A =$ Temperature in c

$O_2 =$ Oxygen in %

	Oil light	**Natural gas**	**Town gas**	**Coal gas**	**Liquid gas**	**Wood (air-dry)**
CO_2max	15.5	11.8	13.7	12.5	13.5	20.3
A_2	0.68	0.66	0.63	0.60	0.63	0.65
B	0.007	0.009	0.011	0.011	0.008	0.008
O_2B	3%	3%	3%	3%	3%	11%

Thermal efficiency of bakries:

The air/fuel ratio is considered the most important controllable parameter in achieving the optimum thermal efficiency. It is also affecting the flue gases temperature, the concentration of CO_2, SO_2 and O_2 in flue gases ,the heat losses and thermal efficiency. Therefore, to obtain the optimum thermal efficiency of the three ovens, six different levels of excess air rate were used. These levels were 0, 10, 20,30,40, and 50% excess air as a ratio of the equivalent air.

The automatic burners are equipped with an air adjustment tool that allows adjusting the combustion air.

$$Et_a = 100 - q_A\ (\%)$$

Converting ppm into volume/weight ratio:

The conversion of ppm values into mg/m^3(milligram per cubic meter) is based on the following conversion factors :

$CO \rightarrow$ 1ppm = 1.25 mg/m^3
$SO_2 \rightarrow$ 1ppm = 2.86 mg/m^3
$N_2O \rightarrow$ 1ppm = 2.05 mg/m^3

RESULTS AND DISCUSSION

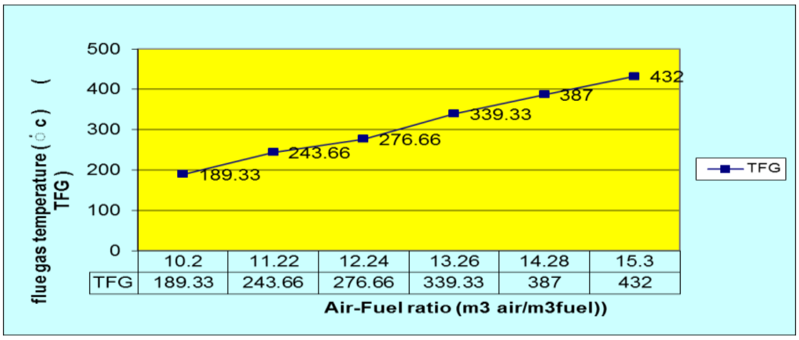
The thermal energy efficiency, the specific energy consumption, and the emission of exhaust gasses of three different balady bread ovens were investigated, and evaluated. The obtained results could be discussed under the following headlines:

Evaluation the thermal energy efficiency,

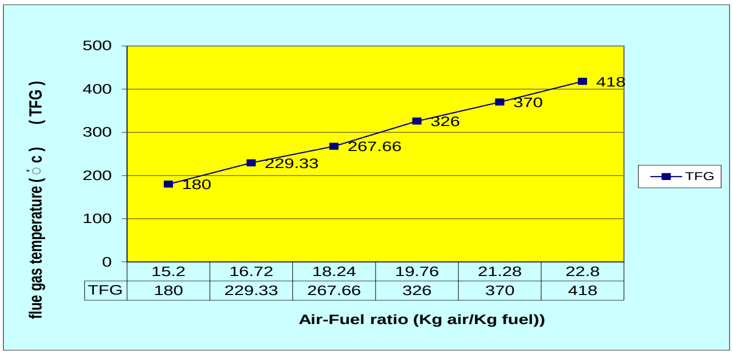
To determine the optimum thermal efficiencies for the three tested ovens it was firstly required illustrating the data about the effects of air/fuel ratio on flue gases temperature, concentration of the O2 and CO2 in flue gases and heat losses.

The effect of air/fuel ratio on flue gases temperature:

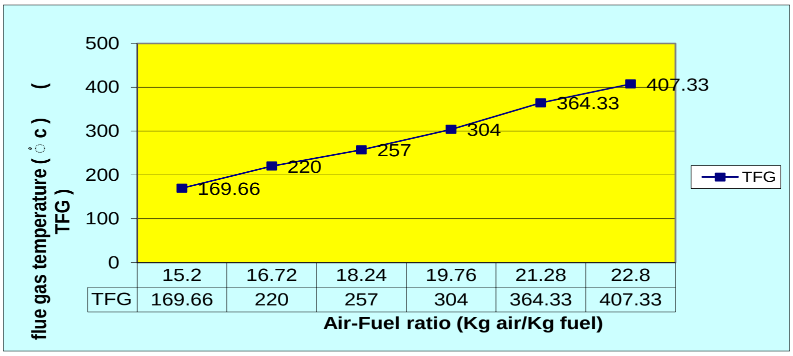
The flue gases temperature (TF_G) as affected by different air/fuel ratio for the three investigated ovens are shown respectively in Fig. 3 (from a to c).



a) For SMA-G oven



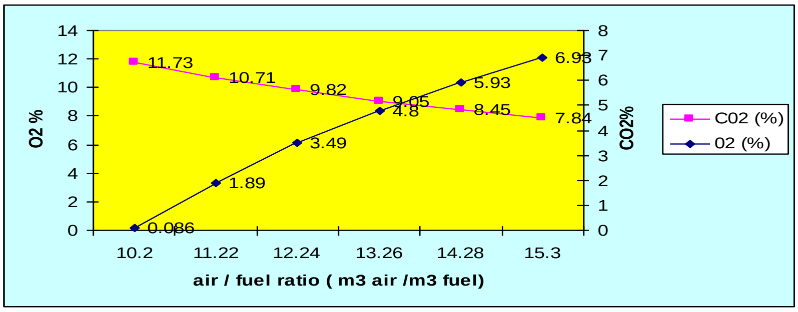
b) For SMA-L oven



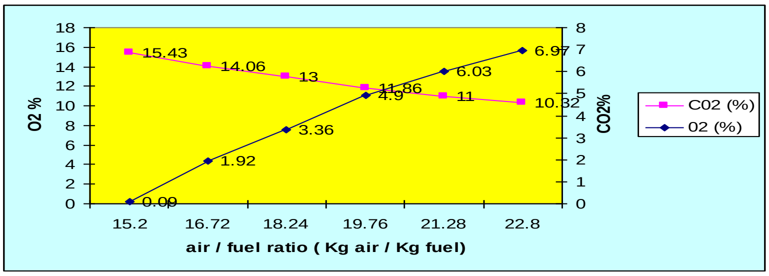
c) For MA-L oven

Fig. (3): The effect of air/fuel ratio on flue gases temperature for the three tested ovens.

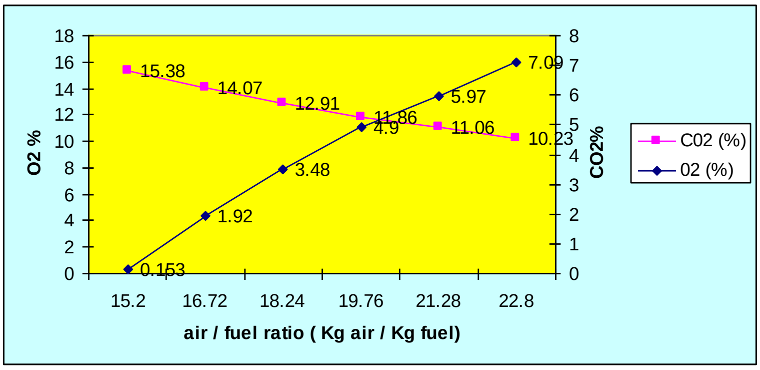
From the shown figures, it is noted that by increasing the air/fuel ratio the flue gas temperature increases also. Regarding that, the flue gas temperature must be held low as possible in order to minimize the flue gas losses and maximize the thermal efficiency of the ovens (EL-kady (2002)). In the other hand, regarding that, the excessive reduction in flue gas temperature {below gases dew point temperature (275 ° C)} does not recommended. Because that the reduction below gases dew point temperature results in corrosion problems due to acid formation. Putting in mind, the above-illustrated facts, and referring Fig.3 (from a to c) it could be stated that the proper flue gases temperature for the three tested ovens are as follows:-



a): For SMA-G.



b): For SMA-L.



c): For MA-L.

Fig. (4): The effect of air/fuel ratio on concentration of O_2 and CO_2 in flue gases for the three tested ovens.

For SMA-G, it was 276.66°C which obtained at air-fuel ratio 12.24 m^3 air/m^3 fuel.

For both (SMA-L and MA-L) were 326, and 304°C respectively. These temperature values obtained at the same A/F ratio of 19.76 kg air /kg fuel.

The effect of air/fuel ratio on concentration of the O_2 and CO_2 in flue gases:

The concentration of $C0_2$and O_2 in the flue gas as affected by A/F ratio for the three investigated ovens are shown respectively in Fig. 4 (from a to c).

From the shown figures it can be noticed in general that for all tested oven the increases of air/fuel ratio causes lower of $C0_2$ concentration and the higher 0_2 concentration. These result trends may be due to the balance of chemical interaction equations, which stated that the higher CO_2 content the lower 0_2 content.

The effect of air/fuel ratio on both of flue gas losess and thermal efficiency:

Fig. 5 (from a to c) shows the relationship between the air/fuel ratio and the flue gases losses and the thermal efficiencies for the three investigated ovens respectively.

The results indicated that the higher air/fuel ratio the higher the flue gases losses and so the lower thermal efficiency. This means that the thermal efficiency is strongly dependent on the air /fuel ratio.

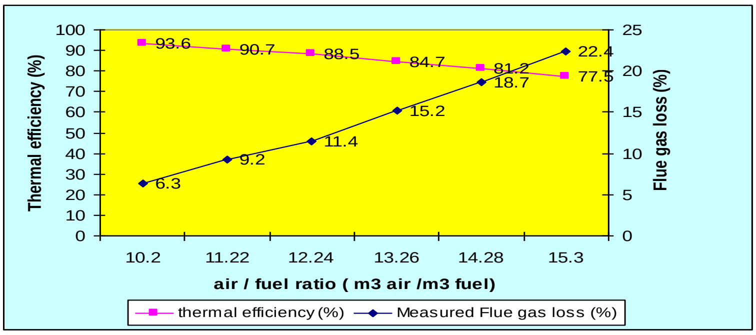
From the obtained results it could be concluded that the optimum thermal efficiency for SMA-G was 88.56% obtained at A/F ratio of 12.24 m^3air/m^3 fuel, and at flue gas temperatures 276.66° C. While, the optimum thermal efficiency for both (SMA-L and MA-L) were 85.54-86.61% respectively. These thermal efficiency values were obtained at the same A/F ratio of 19.76 kg air/kg fuel, and at different flue gas temperatures of 326,and 304° C for (SMA-Land MA-L) respectively.

The result trends are coinciding with that obtained by EL-Kady (2002).

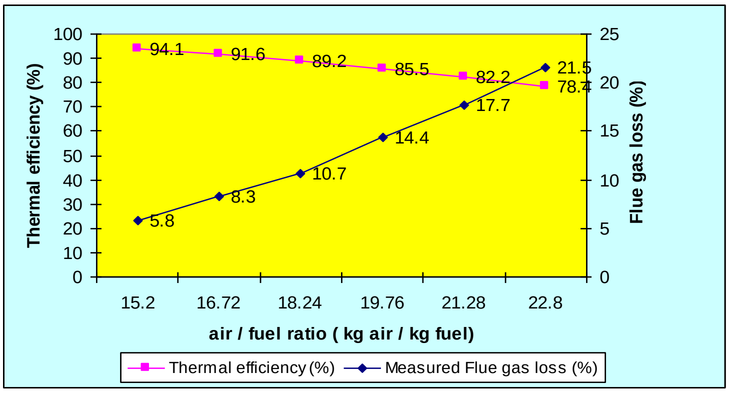
To summarize a comparison between the thermal performance of the tested ovens it could be indicated that the optimum thermal performance [i.e flue gases temperature (TFg), air/fuel ratio, concentration of CO2 and 02 in the flue gases, flue gases loss and thermal efficiency] for the three tested ovens were measured and shown in Table (4) and Figs. (6) and (7).

The obtained measured and calculated values indicated that the three tested ovens were varied in their thermal performance.

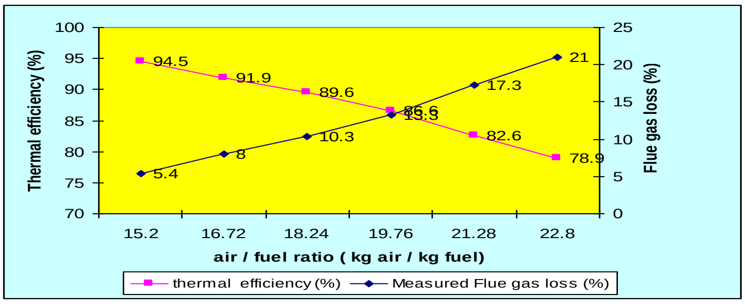
The optimum thermal efficiency for the three different ovens SMA-G, MA-L and SMA-L ovens was 88.56, 86.61 and 85.54 % respectively. Therefore, the greatest optimum thermal efficiency (88.56%) was achieved by SMA-G. The optimum conditions of thermal efficiency [lower values of flue gases temperature (276.66°C) air/fuel ratio (12.24 m^3 air/m^3fuel), and O_2 (3.49 %) in the flue gases, flue gases loss (11.44 %)] were achieved by SMA-G oven.



a): For SMA-G oven.



b): For SMA-L oven.



C): For MA-L oven.

Fig. (5)The effect of air/fuel ratio on both of flue gas losses and thermal efficiency for the three tested ovens

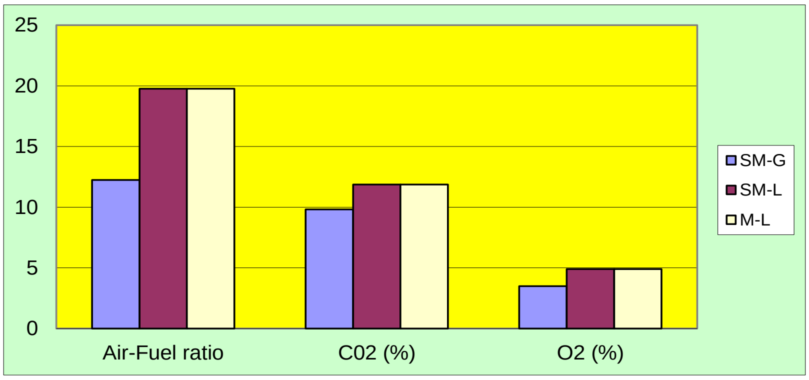


Fig. (6): air-fuel ratio, (CO_2) nd (O_2) measured values for the three different ovens.

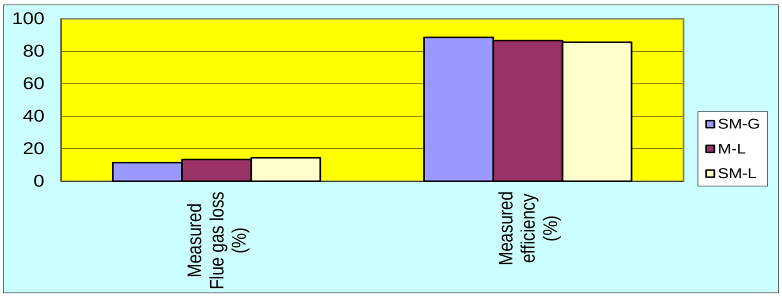


Fig. (7): Flue gases losses and thermal efficiency values for the three different ovens.

Table (4): the optimum thermal efficiencies of the different ovens.

Thermal performance parameter	Oven		
	SMA-G	**SMA-L**	**MA-L**
Air/fuel ratio	12.24	19.76	19.76
Excess air rate %	20	30	30
Ambient temperature T_A(°C)	32.66	33.66	33.33
Flue gas temperature TF_G(°C)	276.66	326	304
$C0_2$ (%)	9.82	11.86	11.86
0_2 (%)	3.49	4.9	4.9
Measured Flue gas loss (%)	11.44	14.46	13.39
Measured thermal efficiency (%)	88.56	85.54	86.61

This indicates that higher thermal efficiency could be achieved at lower values of flue gases temperature, concentration of O_2 in the flue gases and values of air /fuel ratio.

Evaluation the specific fuel energy consumption:

The production rate for both used fuel types solar and natural gas were estimated and tabulated in table (=) in two different units namely (loaves /m^3 fuel) and (loaves / L fuel) measured values of the solar oven SMA-L and MA-L were adjusted to meet the equivalent natural gas values. The adjusted values are shown in Table (5) , The values of the specific fuel consumption in (m^3/kg wheat flour) are shown in Fig.(8) , and the values of the specific fuel energy consumption (MJ/kg wheat flour) are shown in Fig. (9).

Table (5): The fuel energy consumption of three tested ovens.

Performance of the ovens	OVEN		
	M-L	**SM-L**	**SM-G1**
The oven productivity (loaves / hr)	4000.4 ± 2.1747	2351.867 ± 1.8085	2501.067 ± 1.7687
Fuel consumption (m^3 fuel/hr) or (L fuel/hr)	19.6 L fuel/hr	22.32 L fuel/hr	12.66 M^3 fuel/hr
Production rate per fuel unit (loaves /m^3 fuel) or (loaves/L fuel)	202.07 (loaves/Lfuel)	104.38 (loaves/Lfuel)	197.67 (loaves /m^3 fuel)
Production rate per fuel unit (loaves /m^3 fuel)	144.34[*2]	74.56[*]	167.67
Specific Fuel consumption (m3 /kg flour)	0.0712	0.1380	0.052
Specific Fuel energy consumption (MJ /kg flour)	2.7768[**]	5.382[**]	2.028[**]

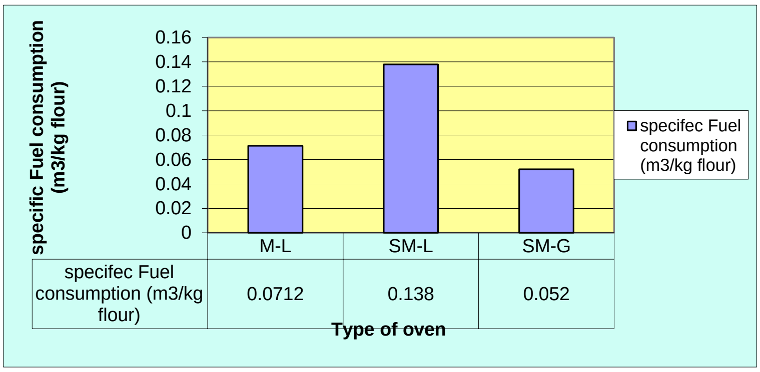


Fig. (8): The specific fuel consumption in (m^3/kg flour)

(*) : Values converted from light fuel oil to equivalent natural gas values in terms of calorific value.
(**) : from heating value of natural gas .

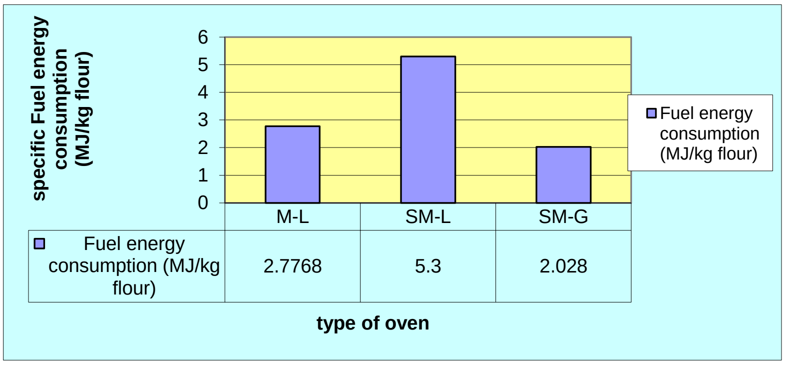


Fig. (9): The specific fuel energy consumption (MJ/kg flour)

From the obtained results it is noted that the least specific fuel energy consumption per kg wheat flour was (2.028 MJ/kg flour) obtained from (SM-G) .at the same time The highest value of specific fuel energy consumption was (5.3 MJ/kg flour) obtained from (SM-L).

The above result trends are in agreement with that obtained by Alain Le-bail et. al (2010) .

Evaluation the emission of exhaust gasses :

The emitted gases i.e. sulfur dioxide (SO_2) , nitrogen monoxide (N_2O),totalhydrocarbon (C_xH_x), benzene,toluene,xylene, and trichloroethylene (TCE) were measured in the ovens by using Ambient air analyzer after determination of the optimum thermal efficiency and the obtained results are shown in Table (3) .

Table(6): Emitted gases outside the oven during baking of balady bread.

Type of oven	Parameters (ppm)						
	SO2	**N2O**	**Total hydrocarbon CXHX**	**Benzene**	**Toluene**	**Xylene**	**Trichloro-ethylene (TCE)**
Allowable limit	0.04	0.09	-	-	-	-	-
SMA-G	**5.7**	**0.75**	**3.85**				
SMA-L	34	3.75	9.2	88	16	18	23
MA-L	15.5	2.5	4.5	71	9	12	18

From the obtained results it is noted that the gases emitted out side the ovens were varied mainly according to the type of fuel used.

The obtained results also revealed that, replacing the natural gas in stead of solar as a fuel can be reduced the environmental pollution associated with the balady bread bakeries under the Egyptian condition. Where's, the recorded data of toxic compounds such as benzene, toluene, xylene, and trichloroethylene (TCE) weren't detected in case of using natural gas. While, these compounds were 71-9-12-18 and 88-16-18-23 ppm for (MA-L, SMA-L) respectively that used solar fuel.

In addition the emission sum-mission of sulfur dioxide (SO_2) and nitrogen monoxide (N_2O) were higher in case of using SMA-L than these of MA-Land SMA-G by about 2.09 times and 5.85 times respectively.

However, the emission from all investigated oven weren't with in the allowed levels recommended by Egyptian Environment low .

CONCLUSION

1. The obtained results indicated that, the minimum flue gases temperature that could minimize the flue gas losses, maximize the thermal efficiency and above the flue gases dew point temperature(275) for SMA-G was 276.66° C obtained at air- fuel ratio 12.24 m^3 air/m^3fuel, While, the flue gases temperature for both (SMA-L and MA-L) were 326,and 304°C respectively. These temperature values were obtained at the same A/F ratio of 19.76 kg air /kg fuel. In addition the greatest optimum thermal efficiency (88.56%) was achieved by SMA-G. The optimum conditions of thermal efficiency [lower values of flue gases temperature (276.66 °C) air-fuel ratio (12.24 m^3 air/m^3fuel), and O2 (3.49 %) in the flue gases, flue gases loss (11.44 %)] were achieved by SMA-G oven.
2. The least specific fuel energy consumption was (2.03 MJ/ kg wheat flour) obtained from (SM-G) .at the same time The highest value of specific fuel energy consumption was (5.38 MJ/ /kg wheat flour) obtained from (SM-L).
3. The gases emitted out side the ovens were varied according to the type of fuel used, replacing the natural gas instead of solar as a fuel reduced the environmental pollution associated with the balady bread bakeries under the Egyptian conditions. Where's, the recorded data of toxic compounds such as benzene, toluene, xylene, and trichloroethylene (TCE) weren’t detected in case of using natural gas. While, these compounds were 71-9-12-18 and 88-16-18-23 ppm for (MA-L, SMA-L) oven respectively that used solar fuel. In addition the emission sum-mission of sulfur dioxide (SO_2) and nitrogen monoxide (N_2O) were higher in case of using SMA-L than these of MA-Land SMA-G by about 2.09 times and 5.85 times respectively. However, the emission from all investigated oven weren't with in the allowed levels recommended by Egyptian Environment low .

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ترشيد الطاقه الحراريه وتقليص الاثر البيئى للغازات المنبعثه فى مخابز الخبز البلدى

على السيد ابوالمجد - عماد الدين امين عبدالله - احمد حمدى جادو
قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة

يهدف هذا البحث إلى الحصول على الكفاءه الحراريه المثلى لثلاث افران تعمل بانواع مختلفه من الوقود وحساب الاستهلاك النوعى للوقود للافران الثلاثه وكذلك تقدير الاثر البيئى للغازات المنبعثه من الافران اثناء عمليه الخبيز. وقد تم اجراء الدراسه على ثلاثه انواع من الافران :

- فرن آلى كامل لانتاج الخبز البلدى يعمل بالوقود السائل (السولار) M-L.
- فرن نصف آلى لانتاج الخبز البلدى يعمل بالوقود السائل (السولار) SMA-L.
- فرن نصف آلى لانتاج الخبز البلدى يعمل بالغاز الطبيعى SMA-G .

حيث أجريت الدراسات الآتيه :

1. تقدير الكفاءه الحراريه المثلى للثلاث افران بدراسه تأثير نسب الهواء للوقود على درجه حراره غازات العادم ،تركيزات ثانى أكسيد الكربون والأكسيجين فى غازات الاحتراق ، فواقد غازات العادم والكفاءه الحراريه. حيث يعتبر نسبه الهواءللوقود احد اهم العوامل التى تؤثر فى الكفاءه الحراريه للافران .
2. تقدير الاداء الحرارى للثلاثه أفران عن طريق دراسه درجه حراره غازات العادم ، نسب الوقود للهواء . تركيزات ثانى اكسيد الكربون والاكسيجين فى غازات الاحتراق ، فواقد غازات العادم والكفاءه الحراريه للافران .
3. تقدير وحساب الاستهلاك النوعى للوقود فى الثلاث افران وعمل مقارنه بينهم .
4. التاثير البيئى للغازات المنبعثه من الافران اثناء عمليه الخبيز مثل ثانى اكسيد الكبريت ، اكاسيد النيتروجين ،الهيدروكربونات الكليه ، ثانى اكسيد الكربون ، البنزين ، الطولوين ، الزيلين ، ثلاثى كلوريد المثيلين .

وقد اسفر إجراء التجارب سالفه الذكر عن الحصول على النتائج الآتيه :

1. نسبه الهواء للوقود والتى تؤدى الى الحصول على الكفاءه المثلى للفرن SMA-G هو12.24متر مكعب هواء لكل متر مكعب وقود وللفرنSMA-Lهى 19.76كجم هواء لكل كجم وقود كنسبه من هواء الاحتراق وللفرن MA-Lهى 19.76 كجم هواء لكل كجم وقود .

- درجه حراره غازات العادم للافران MA-L,SMA-L,SMA-Gهى 276.66و326و304 درجه مئويه على الترتيب عند الكفاءه الحراريه المثلى (اعلى من نقطه الندى 275 درجه مئويه والتى تؤدى الى حدوث مشاكل تتعلق بالتآكل نتيجه تكوين الاحماض) .

2. اختلفت قيم الكفاءه الحراريه للأفران الثلاثه وحصل الفرن SMA-G على اعلى كفاءه 88.56 % تلاه MA-L ثم SMA-L بنسب 86.61% و 85.54 % بالترتيب .
3. اقل استهلاك نوعى للوقود 2.53 ميجا جول لكل كجم دقيق وذلك للفرنSM-G بينما اعلى استهلاك نوعى للوقود 5.38 ميجا جول لكل كجم دقيق وذلك للفرن SM-L
3. تختلف الغازات المنبعثه خارج الافران تبعا لنوع الوقود المستخدم حيث نلاحظ انخفاض فى نسب الانبعاثات فى حاله الافران التى تعمل بالغاز الطبيعى بالمقارنه بالافران التى تعمل بالسولار .

كما لوحظ انبعاث نسبه كبيره من مركبات البنزين - الطولوين - الزيلين - ثلاثى كلوريد المثيلين فى حاله الافران التى تستخدم السولار ولم تظهر فى حاله الافران التى تستخدم وقود الغاز الطبيعى وهذا مضر جدا بالبيئه ونجد ان انبعاث اكاسيد النيتروجين وثانى اكسيد الكبريت فى الثلاث افران غير مطابق للقوانين المصريه .