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FLAT BREADS QUALITIES AND ATTRIBUTES — OVENS DESIGN, ENERGY CONSUMPTION, AND ENVIRONMENTAL CONSERVATION: A REVIEW

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KEY WORDS:
bread quality, physical properties, flat bread, bread staling, oven design, energy consumption, environmental conservation

ABSTRACT
Flat bread is considered a staple food worldwide and especially balady bread in Egypt and the Middle East region. The most common flat bread types produced all over the world, contents, used leavening agents, properties, and countries were reviewed. Also, balady bread ingredients, formula, preparation, dough rheology, baking conditions, as well as physical characteristics, color attributes, sensory evaluation, and freshness or staling retardation of loaves were presented. Flat bread (balady bread) is processed from flattened dough of wheat flour, sodium chloride, water, and yeast and is often served freshly baked and produced in both bakeries and homes. The main features of a balady bread oven, such as composition, construction, dimensions, fuels, emissions, and its effect on the environment and energy consumption, were also mentioned. The common specifications and general design of a balady bread industry oven in Egypt on a commercial scale were presented as follows: Oven length could be more or less than 600 cm depending on available space in the baking building. Also, oven width could be more or less than 90 cm, depending on the needed productivity of bread per hour. To “keep the environment, minimize heat losses, maximize quantity and quality of production, and assure economic visibility,” the determination of oven dimensions, selecting construction materials and transmission systems must be done by oven designers using the oven general model.

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ОСОБЕННОСТИ И СВОЙСТВА ПЛОСКИХ ХЛЕБОБУЛОЧНЫХ ИЗДЕЛИЙ — ДИЗАЙН ПЕЧЕЙ, ЭНЕРГОПОТРЕБЛЕНИЕ И ОХРАНА ОКРУЖАЮЩЕЙ СРЕДЫ: ОБЗОР

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КЛЮЧЕВЫЕ СЛОВА:
качество хлеба, физические свойства, плоский хлеб, черствение хлеба, дизайн печей, энергопотребление и охрана окружающей среды

АННОТАЦИЯ
Плоский хлеб считается главным продуктом питания во всем мире и особенно хлеб балади в Египте и ближневосточном регионе. Сделан обзор наиболее распространенных видов плоского хлеба, производимых во всем мире, составов, используемых разрыхлителей, свойств и стран. Также представлены ингредиенты хлеба балади, рецептура, приготовление, реология теста, условия выпечки, а также физические характеристики, цветовые характеристики, сенсорная оценка, свежесть или замедление черствения хлеба. Плоский хлеб (хлеб балади) вырабатывается из раскатанного теста из пшеничной муки, хлорида натрия, воды и дрожжей, и часто подается свежеиспеченным и изготавливается как в пекарнях, так и в домашних условиях. Также рассматриваются основные характеристики печи для хлеба балади, такие как структура, конструкция, размеры, топливо, эмиссии, и её влияние на окружающую среду и потребление энергии. Распространенные спецификации и общий дизайн промышленной печи для хлеба балади в Египте, работающей в промышленном масштабе, представлены следующим образом: длина печи может быть более или менее 600 см в зависимости от доступного пространства здания пекарни. Также ширина печи может быть более или менее 90 см в зависимости от требуемого объема выпечки хлеба в час. Для «сохранения окружающей среды, минимизации теплопотерь, максимального повышения количества и качества продукции и обеспечения экономической видимости», разработчики печей должны определять размеры печи, выбирать конструкционные материалы и системы передачи, используя общую модель печи.

1. Introduction

Balady bread, widely consumed in the Middle East region, especially in Egypt, is flat bread [1]. Balady bread is the most strategically important food commodity in Egypt. The consumption of wheat (2019/2020) was 20.4 million metric tons, from such an amount 270 million balady bread loaves were baked every day [2]. There are many differences between flat and pan breads (Table 1), as reported by Gocmen et al. [3]. Based on the previous publications, there is a lack of information about flat bread, especially Egyptian balady bread, therefore, this study reviews flat bread types, balady bread quality characteristics of both raw materials and end products, as well as balady bread oven constituents, structures, dimensions, specifications, emissions, and design used in balady bread making.

Table 1. **Differences between flat and pan breads [3]**
Таблица 1. **Различия между плоским и формовым хлебом [3]**

Flat bread	Pan bread
Lower specific volume	Higher specific volume
High crust and crumb ratio	Low crust and crumb ratio
Leavened flat bread has a shorter fermentation time	Leavened pan bread has longer fermentation time
Higher baking temperature	Lower baking temperature
Shorter baking time	Longer baking time

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2. Objects and methods

The sources of information were the following scientific databases: PubMed, Scopus, Science Direct, Google Scholar and Research Gate. The search strategy included the following keywords: bread quality, physical properties, flat bread, bread staling, oven design, energy consumption, environmental conservation. The following acceptance criteria for research characterization were considered: The most common flat bread types, contents, used leavening agents, properties, the main features of a balady bread oven and the common specifications and general design of a balady bread industry oven in Egypt on a commercial scale. All of the figures in this article are the authors' own.

The parameters of the publications were as follows: publication from 1979 until 2024 (58 references were selected for this review); language: English. Exclusion criteria: no access to the full text articles. Based on the review, the authors compiled information on discussion of flat breads qualities and attributes — ovens design, energy consumption, and environmental conservation.

3. Background on flat bread

3.1. Bread raw materials

Raw materials used for balady bread making include extracted wheat (*Triticum aestivum*) flour (85–87%) with protein content (10–12%) and prepared using starter (previously fermented dough containing microbes) [1]. Table 2 shows the proximate chemical composition of hard wheat flour (82% extraction) used for balady bread processing. Flat bread (balady bread) is processed from a flattened dough of wheat flour, sodium chloride, water, and yeast and is often served freshly baked and produced in both bakeries and homes [4]. Table 3 presents raw materials (formula) used for balady bread manufacturing as mentioned by Mousa et al. [5] and Hussein et al. [6]. Likewise, Table 4 shows the formula used for Arabic (pita) bread processing as stated by Elkatry et al. [7].

Table 2. **Proximate chemical composition of hard wheat flour (82% extraction) used in balady bread making (on a dry weight basis)**

Таблица 2. **Приближённый химический состав муки из твердой пшеницы (82% экстракции), используемой для приготовления хлеба балади (в пересчёте на сухую массу)**

Parameters	%	References
Moisture	13.02	[6]
Ash	1.47	
Fiber	1.65	
Protein	11.75	
Lipid	1.81	
CHO	83.32	
Protein	6–12	[8]
Lipid	1–4	
Starch	55–75	
Soluble CHO	1–2	
Fiber	3–7	
Ash	1–2	
Protein	13.07	[9]
Fat	1.85	
Fiber	1.28	
Ash	1.05	
CHO	82.75	

Table 3. **Formula of balady bread**

Таблица 3. **Рецептура хлеба балади**

Raw material	%	References
Flour	100	[5]
Water	70–80	
Salt	0.5–1.5	
Starter (fermented dough)	12–17	
Hard wheat (82% ext.)	100	[6]
Salt	1	
Dry yeast *	1.5	
Water	70–80	

* *Saccharomyces cerevisiae.*

Table 4. **Formula of Arabic (pita, shamy) bread**

Таблица 4. **Рецептура арабского хлеба (пита, шами)**

Raw material	%	References
Wheat flour 72%	100	[7]
Water	60	
Salt	2	
Yeast	1.5	
Sugar	2	

3.2. Rheological properties of dough

Various rheological parameters of farinograph and extensograph are listed in Table 5. These parameters include water absorption, arrival time, dough development time, dough stability, and weakening of Balady bread dough (wheat flour 82% extraction). Also, parameters of extensogram (Table 5) include dough extensibility, resistance to extension, maximum resistance to extension, dough energy, and proportional number as reported by Hussein et al. [6].

Table 5. **Farinograph and Extensograph parameters of balady bread flour [6]**

Таблица 5. **Фаринографические и экстенсографические параметры муки для хлеба балади** [6]

Sample	Farinograph parameters				
	Water absorption (%)	Arrival time (min)	Dough development (min)	Dough stability (min)	Weakening (BU)
Balady bread flour (82% Extr)	66.4	1.0	2.5	13.5	20
	Extensograph parameters				
	Dough extensibility (E) (cm)	Resistance to extension (R) (BU)	Maximum resistance to extension (BU)	Proportional number (R/E)	Dough energy (cm^2)
	155	490	410	2.64	97

3.3. Preparation of balady bread

To one thousand gram of wheat flour (82% extraction), 10 g of dry yeast, 15 g of sodium chloride, and 760 ml of water were added and mixed in a mixer for 25 min. The formed dough was left for 45 min for fermentation at 30 °C and 85% relative humidity. The dough was divided into pieces (160 g each), sprinkled with a bran layer, and left for another 45 min to complete the fermentation. The fermented dough pieces were flattened to about 20 cm in diameter and 0.5 cm thickness and baked at 450–500 °C for 1.5–2 min. Bread loaves were allowed to cool on wooden racks for 30 min at room temperature and then packed in polyethylene bags [6,10].

3.4. Bread baking

Bread baking is the critical step in which the dough is transformed into a light, porous, readily digestible, and flavorful product, under the impact of heat. Thus, good quality bread production requires a carefully controlled baking process, including the rate and amount of heat application and the humidity level in the baking chamber and baking time [11]. Balady bread is a flat, circular loaf consisting of two layers and usually baked at high temperatures for a few minutes [10].

Also, Al-Hajji et al. [12] indicated that temperatures inside the Arabic flat bread during baking do not increase more than a few degrees Celsius above 100. However, this is enough to provide sufficient generation of steam with a high enough internal pressure to drive the characteristic puffing that occurs in successful bread baking. The end point of the baking process depends on quality aspects that are critical in the acceptance of the bread by a consumer, such as color, texture, and flavor [13,14]. Furthermore, Table 6 exhibits baking temperatures and times used for balady bread making as reported by El-Samahy and Tsen [1] and Hallab et al. [15].

Table 6. **Balady bread baking conditions**

Таблица 6. **Условия выпечки хлеба балади**

Baking temperature, °C	Time, min.	References
400–600	0.66–1	[15]
300–350	3–4	[1]
450–500	1–2	[10]

3.5. The common types of flat breads produced in worldwide

Balady bread is flat and circular, formed from two separated thin layers (crust: upper layer; and crumb: lower layer), 1 cm thick, the loaf diameter ranged from 15 to 20 cm, and the weight ranged from 70 to 90 gm (Table 7). It characteristically consists of two layers, which form as a result of internal puffing during baking [12]. Table 8 illustrates some types of flat breads (their formulas and characteristics) produced in different countries. Also, Figure 1 shows the classification of flat bread in various countries.

Table 7. **Proximate chemical composition of balady bread**
Таблица 7. **Приближённый химический состав хлеба балади**

Parameters	%	References
Moisture	34.52	[6]
Ash	1.50	
Fiber	1.65	
Protein	11.60	
Lipid	1.62	
CHO	83.63	

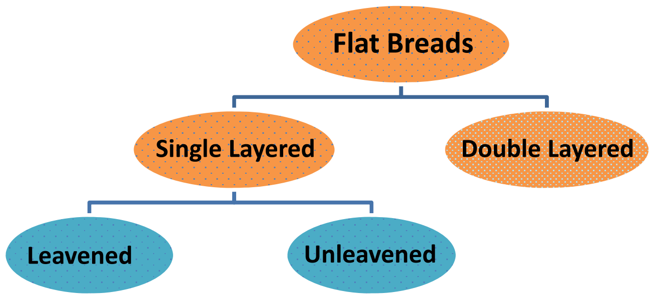

Figure 1. **Classification of flat bread**
Рисунок 1. **Классификация плоского хлеба**

3.6. Bread quality

3.6.1 Physical characteristics of bread

In Egypt, as well as the Middle East, the most popular type of bread is a flat (balady bread), circular loaf (1 cm thickness, 10 to 30 cm diameter) consisting of two layers [19].

Physical characteristics include weight (g), volume (cm^3), and specific volume (cm^3/g) of prepared bread samples.

3.6.2. Color attributes of balady bread

Lightness (L), red content (a) and yellow content (b) values of crust and crumb of different prepared bread samples were determined by using a Hunter Lab color measurement system.

Color analysis of food is an important field, always related strongly to market and consumer acceptability, as it controls the first impression of any food product. L^* a^* b^* values (L^* value is a measure of lightness ranging from 0 (black) to 100 (white), a^* value ranges from −100 (greenness) to +100 (redness) and b^* value ranges from −100 (blueness) to +100 (yellowness) describe the color differences between samples (either crust or crumb colors).

Changes in bread color may be due to baking at different temperatures and times and consequently the browning reaction that occurs in bread samples. Elawad et al., [11] stated that the color of bread depends on the moisture evaporation from dough and Millard reaction during the baking process. The lower crust lightness (L^*) of bread crust was probably related to baking temperature. Baking temperature and time reduced all the color values [20]. Increasing baking temperature and time caused an obvious reduction in L^* value thus, darker bread color. Temperature and time of baking process had negative linear relationship with L^*, a^* and b^* of bread color values [11]. Breads baked at a higher temperature were generally of better quality than those baked at a lower temperature. Lower baking temperatures failed to yield breads with desirable bread crust and crumb color [10].

Table 8. **The most common flat bread types produced worldwide**
Таблица 8. **Наиболее распространенные виды плоского хлеба, производимого в мире**

Bread name	Contents	Raising agents	Properties	Zone	References
Balady bread	Hard wheat (82% ext.), salt, starter (fermented dough), or dry yeast and water	Yeast or starter (fermented dough)	Flat, circular, separated two thin layers (crust: upper layer; and crumb: lower layer), 1 cm thickness, loaf diameter ranged from 15 to 20 cm and weight ranged from 70 to 90 gm.	Egypt and the Middle East	[6]
Arabic (pita, shamy, Syrian, pocket) bread	Flour, water, baker's yeast and salt	Yeast	Round, leavened two (double) layered flat breads	The Middle East	[3]
Egyptian Shamsi bread	Flour, water, baker's yeast and salt	Yeast + sun heat, i. e., open air, under the direct sunlight	Round in shape, single layered, of about 15–20 cm diameter and 10 cm thickness.	Egypt	[16]
Tandoori (Taftoon)	Wheat flour, yeast, or sour dough	Yeast or sour dough	A single layer, circular in shape, 40–50 cm diameter	Iran, Pakistan, and India	[17]
Parotta	Whole wheat flour with 2.5% salt, 65% water, and 40% shortening	unleavened	Flexible handfeel, soft and slightly chewy texture, one layer	India	[18]
Puri	Fried product (deep-fat-fried in preheated oil at 180–200 °C for 25 s) prepared from whole wheat flour	unleavened	Fried product and consumed as snacks	India, Pakistan, and Bangladesh	
Lavash	Hard wheat (82% ext.)	unleavened	Single-layered, has an oval or rectangular (60–70 cm long, 30–40 cm wide) shape and a 2 to 3 mm thickness with a creamy white color	South Asia	
Barbari	Wheat flour, baking soda, mixed in the boiling water	baking soda	The bread is usually 70 to 80 cm long and 25 to 30 cm wide with a thickness of about 3.5 cm	Iran	
Chapatti	Whole wheat flour, salt, oil, and an appropriate amount of water	unleavened	Single layered round in shape of about 15 cm diameter and 0.2 cm thickness	India	[3]
Sangak	Flour of 95% extraction rate, salt (1.5%), sourdough (20%), yeast (0.5%), and water (85%)	Yeast and sour dough	Sourdough flat bread, 70–80 cm long, 40–50 cm wide, and 3–5 mm thick; its surface is sprinkled with sesame	Iran	
Rye flat bread	Barley, oat, rye, and wheat flours, yeast, salt, and sugar with water	Yeast	0.7 to 1.0 cm thickness. Round (5.0 cm diameter)	Scandinavian countries	
Tortilla	Finely ground maize (corn) or wheat flour	unleavened	Thin, one (single) layered flat bread, a flexible texture	Central and South America	
Bazlama	Wheat flour, yeast, salt, sugar, yoghurt, and water	Yeast	Single layered, flat, circular, thickness 3 cm and diameter (10 to 20 cm)	Turkey and the Middle East	
Pide	Flour, salt, water, shortening, sugar, yeast	Yeast	Round shaped flat bread, thickness 1.5–2 cm and diameter 20–25 cm	Turkey	
Yufka	Flour, water, salt, a little vinegar or lemon juice, very little olive oil	unleavened	Round, cream-colored, and single layered flat bread, thickness 1 to 2 mm, diameter 40 to 50 mm	Turkey	

3.6.3. Sensory evaluation of bread

Fresh samples of the different substitutes of balady bread were given three-digit codes and organoleptically evaluated by semi-trained panelists. All samples were evaluated for crust color, crumb color, taste, odor, and overall acceptability on a ten-point hedonic scale, on which a score of 10 represented attributes most liked; 5 represented attributes at an unacceptable margin; and 1 represented attributes most disliked, according to Stone and Sidel [21].

3.6.4. Freshness of Balady bread (staling retardation)

Bread staling is a mix of physical and chemical changes in the bread quality, i. e., crumb hardening, crust softening, and loss of fresh flavor [22,23,24]. Up to date, staling mechanisms have not been well understood. However, the retrogradation of starch (recrystallization) and the water loss have been considered by many authors to be the most important factors affecting the staling [24,25,26].

Various procedures were used for assessing the bread staling rate during storage, such as the traditional Alkaline Water Retention Capacity (AWRC), Texture Profile Analysis (TPA), Thermal Analysis [27], calorimetric methods [28], X-ray crystallography [29], NMR spectroscopy [30,31]. Staling was retarded using either different antistaling agents during the preparation of bread dough as a pretreatment or bread freezing as a post-treatment.

4. Bread oven and its effect on environment, energy consumption

The traditional baking ovens are built by local labors without any design principles, which are used to build the improved baking oven. Therefore, the improved baking oven is more efficient than traditional baking ovens in terms of heat and mass transfer, baking time, and product quality [32]. Energy efficiency of solid fuel bread ovens is 49% at a permanent temperature value in the baking chamber of 220 °C [33]. Local bakers prefer baking as a career but are hindered by financing options and need help as they could not meet microfinance requirements that guarantee the loan payback [34]. The consumed specific energy was 3.57, 2.92, 2.54 and 1.93 kWhkg-1 for Magr Baladi bread oven, while it was 4.35, 3.54, 3.11 and 2.53 kWhkg-1 for Mawi Baladi bread oven at belt speeds 1.18,1.97, 2.40 and 3.55 ms^{-1}, respectively [35]. In a small-scale bread production oven, the baking capacity, baking efficiency, weight loss and optimum baking temperature were: 101.9 kg/h, 46.44% (wood-fired); 70.34% (gas-fired), 13.5 g (wood-fired); and 25.5 g (gas-fired), 150 °C, respectively [36]. Combustion of biomass in small-scale bakery ovens (Wood-Fired Bakery Oven) is widely used in many countries. Although there have been three decades of policies against biomass-based cooking in Africa, demand for fuel wood continues to increase. They depend mainly on fuel wood, collected manually from the surrounding forests, or purchased from (mostly female) suppliers, retailers, or wholesalers [37]. Design and construction of ovens for baking bread are considered complex scientific and industrial problems. Therefore, using simulation models in motion studies of heating gases inside oven spaces is very important in heat uniformity distribution to increase bread quality and decrease both fuel consumption and bad environmental impact [38]. Baking requires air temperatures ranging from 200 °C to 250 °C. Such temperatures can be achieved using solar energy, which is abundant in the developing countries suffering from high energy costs [39].

Traditional cooking methods using fuel woods cause air pollution and land degradation on the local and regional levels. Therefore, using four-reflector solar baking oven is considered a suitable solution for overcoming these problems [40]. A huge part of energy obtained from fuelwood is wasted in non-conventional ovens. Therefore, improvements in efficient utilization of fuelwood in nonconventional bakery ovens are needed [41]. Volatile compounds are lost in the high temperature oven during baking and toasting of gluten-free bread dough in comparison with wheat bread, which could partially explain the richer aroma in wheat bread [42]. The small-scale single-powered baking oven using wood fuel was successfully modified and optimized into a dual-powered oven using fuel gas [36]. The bread is considered one of the basic elements of people life and the main part of their food throughout the historical eras [43]. Temperature uniformity inside the oven leads to good bread quality and is more energy-efficient due to low specific energy consumption [44]. Good thermal insulation of the walls, closing the handling gates using transparent panels, and placing temperature sensors inside the ovens are important design criteria to reduce heat loss and increase the efficiency of energy use for bread baking [45]. Backing time is very important, since the porosity, mean pore volume, and mean coordination number of spaces in bread increase with increasing time inside the oven; and local cell wall thickness decreases with time increase [46]. Electric resistance (ER) baking is a method of baking bread in many countries. This method is based on heating dough as an electric resistor. Briefly, when a current is passed through a dough, heat is generated inside the dough; the amount of generated heat depends on the used current, resistance of used dough and current passage time [47]. Indirect radiation-cyclotherm, indirect convection, hybrid, and industrial tunnel-ITO are used for baking bread with modification of the quality parameters of the crackers [48].

Optimization of the bread-baking process depends on supply and control of heat within the oven with minimal loss. While, the available data on optimizing burner designs for efficient heat supply is very limited [49]. The bread weight loss is increased with increasing oven temperature. Due to increasing oven temperatures from 180 to 220 °C, the bread temperature increased from 112.73 to 168.49 °C and the bread weight loss increased from 22.40 to 52.46% [50]. Wood specific consumptions were found to be 0.55 and 0.90 kg of wood per kg of wheat flour baked using the indirect and semi-direct ovens, respectively. Also, variation of the temperature distribution during the baking process was influencing the quality of the baked bread [51]. The charcoal ovens for baking bread could be constructed with locally available materials (mild steel and angle bars). The maximum temperature attainable with an oven with an area of 315000 mm^2 is about 500 °C and capable of generating 1488 KJ of heat energy [52]. The thermal efficiency of volumetric ceramic (porous) oven technology can be reached at 60% of the total exchanged thermal energy. But, its application in the food industry is not found [53].

The bread baking ovens are thermally insulated chambers. It is the most widely used appliance in the food industry [45]. An electric coil heater and the gas burner with temperature regulator are used in one chamber of a locally made oven. The maximum temperature of 220 °C was recorded through the baking process. Insulated material (slag wool) that has a thermal conductivity of 0.042 W/m °C was used [54]. Weight loss of bread is increasing with increasing oven temperature. Whereas with increasing oven temperature from 180 to 220 °C, the bread increased temperature from 112.73 to 168.49 °C and the weight loss of bread increased from 22.40 to 52.46% [50]. Using electrical resistors and heat regulators in baking ovens gives great potential for controlling the quality of bread in comparison with other sources [55]. In the evaluation process of the effect of wheat flour substitution by different levels of whole barley flour, the flat loaves were proofed at temperatures from 380 to 450 °C for 1–2 min inside the oven [56]. The optimum baking time and temperature were (20 min) and 200 °C for a rotary oven at 10 rpm oven rack speed. The rotary oven could be used for both domestic and industrial production of bread and other bakery products [57]. Numerical results in using ohmic heating technology showed that the linear evolution of temperature with heating time was mainly caused by heat losses [58]. Energy source and control of heat within ovens chambers with minimal loss are considered integral processes in optimizing both quality and quantity of the bread-baking process [49].

5. General model of balady bread ovens in Egypt

A field survey in Egypt was done to determine the main features of balady bread ovens in Egypt. Oven dimensions, construction materials, heating systems, and mechanical tools were recorded and analyzed to produce a general model. Concrete footings with a thickness of 30 cm are constructed to cover soil under the ovens. Oven walls and ceilings are constructed from double layers of thermal clay bricks separated with natural isolation materials. Natural cement made of clay soil is used between bricks in the construction process of both walls and ceilings. Oven ceilings are constructed as cylindrical arc made of thermal bricks and natural cement. The oven external cover made of stainless steel sheets is constructed to improve the external appearance and protect the oven. A steel conveyor made of grades and chains is used to move breads from entrance and exit gates through the baking process. Three phase electric motor contacted with gearbox to move the steel conveyor at linear suitable speed. Gas flamers are used as energy sources inside ovens for the baking process. Exhaust systems consist of a stuck and chimney that is used to divert oven exhaust gases outside in high points over the building.

Usually, the balady bread ovens are constructed in three stages. Figure 2 shows the construction of oven walls from zero level to 40 cm above the concrete footing. The concrete footing dimensions are 230 × 600 × 30 cm for width, length, and height, respectively. Oven dimensions at the first stage are 180 × 400 × 40 cm for width, length and height respectively. Dimensions of oven internal space are 90 × 400 × 40 cm for width, length, and height. Two extensions with dimensions of 115 × 87.5 × 40 cm for width, length and height are found at the entrance and exit gates of the oven. Oven walls are constructed of double walls of thermal bricks separated by natural isolation materials called “clay soil”. Figure 3 shows the construction of oven walls from 40 to 115 cm above the concrete footing.

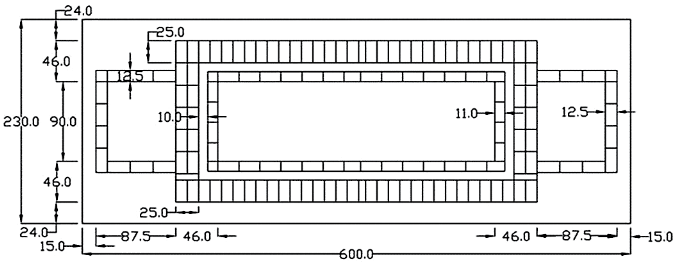

Figure 2. **First stage of the oven walls construction from zero level to 40 cm above the concrete base**
Рисунок 2. **Первая стадия конструирования стен печи с нулевого уровня до 40 см выше бетонного основания**

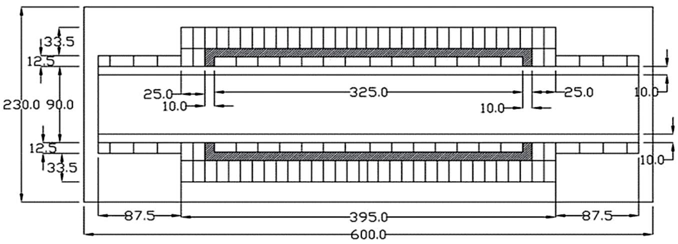

Figure 3. **Second stage of the oven walls construction from 40 cm to 115 cm above the concrete base**
Рисунок 3. **Вторая стадия конструирования стен печи с 40 см до 115 см выше бетонного основания**

At 40 cm level iron bars are installed on side walls to control movement of chain grades conveyor from the entrance gate to the exit gate. Dimensions of the chain grades conveyor are 90×585 cm for width and length, respectively. Figure 4 shows the installation process of chain grades conveyor on the fixed steel bars. A clearance of 5 cm is left between side walls and chain grades conveyor to keep flexibility to replace any part of chain grades conveyor when doing maintenance. Chain grades conveyor is extended 87.5 cm out of entrance and exit gates to keep the baker away from the direct heat.

Figure 5 shows a side view of the oven containing concrete footing, oven side wall and oven extension. Two gas flamers are installed, the first is fixed on one of the side walls between the two layers of the chain grades conveyor for heating chain grades under bread dough, but the second is fixed above the exit gate for heating air around bread dough. Chimneys with stuck are installed above the oven exit gate to ensure getting rid of exhaust gases outside the baking building. Figure 6 shows front and back view details of the oven containing a concrete base, brick walls, isolation material, chain grades conveyor, baking space, and bread dough at the entrance gate. It also shows concrete base, brick walls, isolation material, chain grades conveyor, gas flamer, baking space, and bread at exit gate.

Figure 7 shows a longitudinal section of the oven containing a concrete base, brick walls, isolation material, chain grades conveyor, gas flamer, baking space, and bread dough motion on the chain grades conveyor. Due to the high temperature of the chain grades conveyor under bread dough and the high temperature of air around bread dough, the bread dough is swelling in a semi sphere shape, containing vapor and gases inside. Figure 8 shows an oven cross sectional area containing all details mentioned above. Figure 9 shows the external cover and some

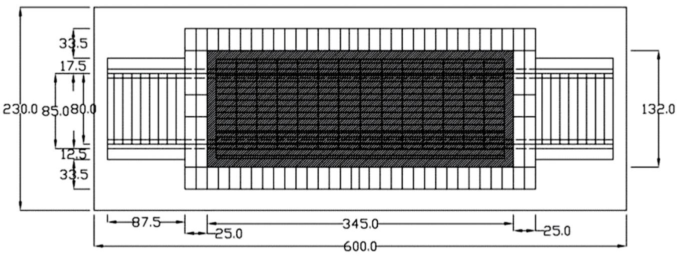

Figure 4. **Final stage of the oven walls construction and chain conveyor installation**
Рисунок 4. **Финальная стадия конструирования стен печи и установка цепного конвейера**

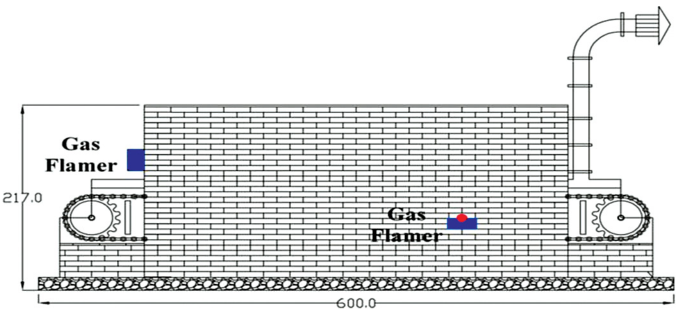

Figure 5. **Side view of the oven**
Рисунок 5. **Боковая проекция печи**

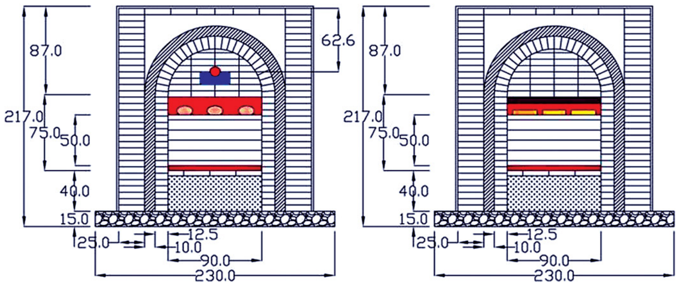

Figure 6. **Front and back views of the oven**
Рисунок 6. **Фронтальная и задняя проекции печи**

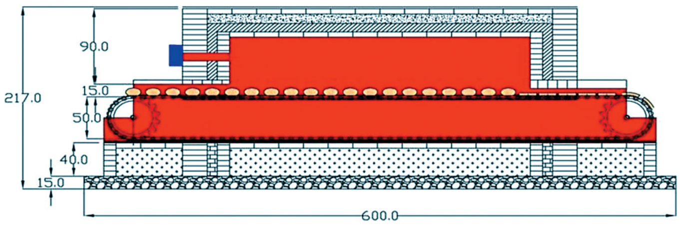

Figure 7. **Longitudinal section of the oven**
Рисунок 7. **Продольный разрез печи**

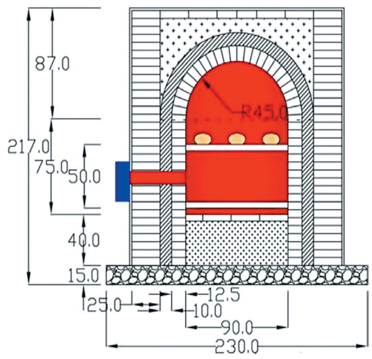

Figure 8. **Cross sectional area of the oven**
Рисунок 8. **Поперечное сечение печи**

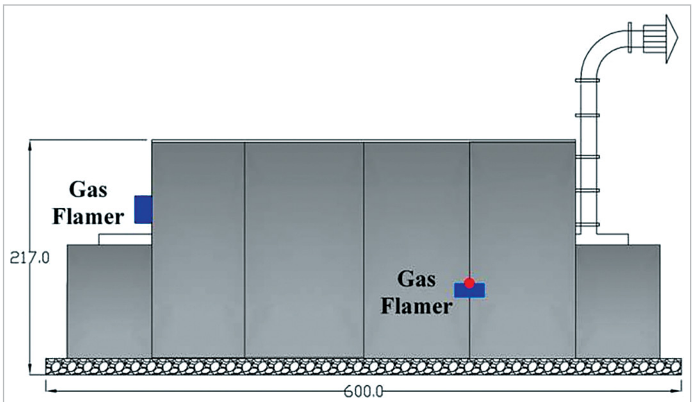

Figure 9. **Side view of the oven covered with stainless steel sheets**
Рисунок 9. **Боковая проекция печи, покрытой листами из нержавеющей стали**

components of the oven. Usually, the external cover is made of a stainless steel layer around the oven body. This cover is very important in the external cleaning and protecting process of the oven. Figure 10 shows details of the chain grades conveyor, electric motor, and transmission system from the electric motor to the chain grades conveyor through the baking process.

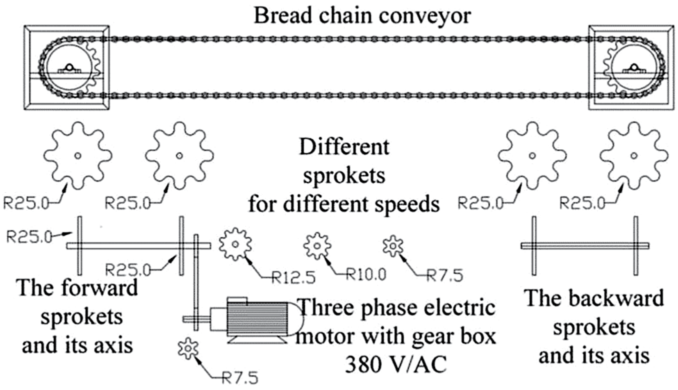

Figure 10. **Mechanical system for bread chain conveyor movement**
Рисунок 10. **Механическая система для движения цепного конвейера для хлеба**

The mentioned above is the common specifications and general design of balady bread industry oven in Egypt on a commercial scale. Oven length could be more or less than 600 cm depending on available space in the baking building. Also, oven width could be more or less than 90 cm depending on the needed productivity of bread per hour. However, the commercial bread ovens in Egypt are working under the control of the governmental environmental associations. In general, balady bread ovens could be constructed by both ordinary construction workers and ordinary technicians in Egypt. To "keep the environment, minimize heat losses, maximize quantity and quality of production, and assure economic visibility", the determination of oven dimensions, selecting construction materials, and transmission systems must be done by oven designers.

6. Conclusion

Flat bread is consumed with almost every meal in Egypt and the Middle East. Manufacturing of balady bread requires special characteristics in both raw materials and dough. Balady bread is made mostly from wheat flour, water, sodium chloride, and yeast. Their main technical characteristics could be summarized as follows: Flour was from hard wheat (85% extraction), the leavening agent was either compressed yeast (*Saccharomyces cerevisiae*) or starter (fermented dough), salt, and water. The baking temperatures were 400–500 °C for 1–2 minutes. For protecting the environment, heat loss minimization, quantity maximization, improving quality of production and assuring economic visibility, determination of oven dimensions, selecting construction materials and transmission systems must be done by oven designers. More development and further studies in flat bread raw materials, production, used ovens, and fuels are needed.

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Contribution	Критерии авторства
Authors equally relevant to the writing of the manuscript, and equally responsible for plagiarism.	Авторы в равных долях имеют отношение к написанию рукописи и одинаково несут ответственность за плагиат
Conflict of interest	**Конфликт интересов**
The authors declare no conflict of interest.	Авторы заявляют об отсутствии конфликта интересов.