ECOFRIENDLY DESIGN OF A COMMERCIAL REFRIGERATOR FOR ENERGY EFFICIENCY LABEL

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Abstract

Adopting hydrocarbon-based refrigerants (R290) and environmentally friendly designs can significantly positively impact energy consumption reduction and sustainability within the food service sector. In commercial kitchens, energy-intensive appliances like refrigerators, ovens, and dishwashers are prevalent, consuming more energy than their household counterparts. These products come in various models and sizes based on enterprise needs. Energy efficiency labels are mandatory for many household products, such as white goods (e.g., refrigerators, washing machines) and electronic devices (e.g., screens), reflecting their energy performance. However, the energy efficiency label is currently limited to commercial coolers (refrigerators and freezers) in the commercial kitchen realm, following EU regulations 2015/1094 and 2015/1095. Ozti manufactures cooler products of diverse models and capacities, emphasizing the importance of energy consumption performance. The study evaluated the energy consumption performance of an innovative commercial refrigerator prototype. This evaluation included using M packages (Tylose test packages) during the test phase, adhering to the EN16825 standard. Apart from eco-friendly design considerations, the appropriate selection and placement of equipment like compressors and evaporators played a crucial role. As a result of employing hydrocarbon-containing refrigerant gas, the commercial refrigerator prototype demonstrated an impressive reduction of approximately 30% in energy consumption.

Keywords: *Commercial refrigerator, energy efficiency label, eco-friendly design, energy consumption*

1. INTRODUCTION

In addition to the continuous consumption of energy resources and the process of obtaining energy is difficult, studies on energy efficiency have increased in recent years in the face of negative effects in terms of global warming. The applications of energy efficiency labels for many household appliances (refrigerators, dishwashers, televisions, etc.) may differ according to countries [1-9]. According to the regulations made by the European Union in 2021 for household products, changes have been made to the energy efficiency labels [10,11]. In the commercial kitchen area, energy efficiency label applications for only commercial refrigeration products (refrigerators and freezers) have become mandatory among all commercial kitchen products (ovens, dishwashers, fryers, etc.).

Our company has commercial refrigeration products (refrigerator and deep freezer) in various models (horizontal and vertical type) and capacities (single door, double door, glass or stainless door, drawer, etc.). Energy efficiency studies aimed at making products available in large markets with developing technologies and environmentally friendly products are gaining importance for all companies. In order to obtain environmentally friendly products in commercial refrigerators, it is extremely important to develop original designs and the compatibility of various equipment (compressor, evaporator, etc.) with the refrigerant to be selected.

It has been determined that most of the literature on energy efficiency and energy label studies in refrigerating products has been made for household refrigerating appliances. The studies on commercial refrigerant products have been determined to be quite limited. Below are summaries of various literature studies on energy efficiency and energy labeling.

Energy efficiency standards and energy label applications in various countries for household refrigerators and freezers were examined by Mahlia and Saidur. A schematic representation of the relationship between the test procedure, standards, and labels is given in Fig. 1 [1].

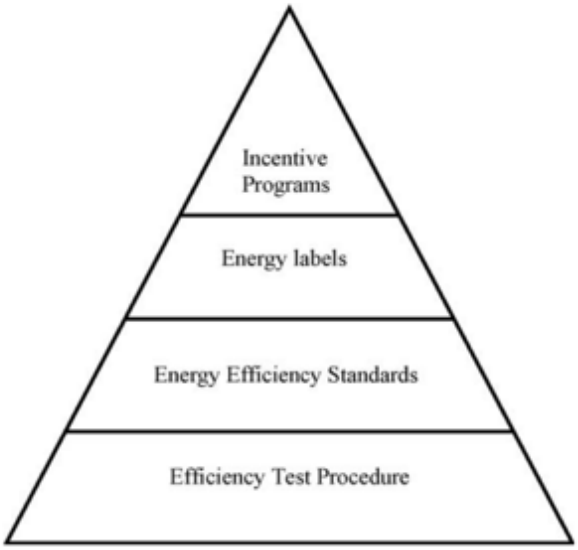

Fig. 1. Schematic representation of the relationship between the test procedure, standards and labels [1].

Mahlia and Saidur emphasized that introducing energy efficiency labels will increase the availability of more efficient products and lead to a transformation in the market. They also reported that consumers can buy more efficient products due to energy labels. The expected distribution in the market with standards and energy label applications is given in Fig. 2 [1].

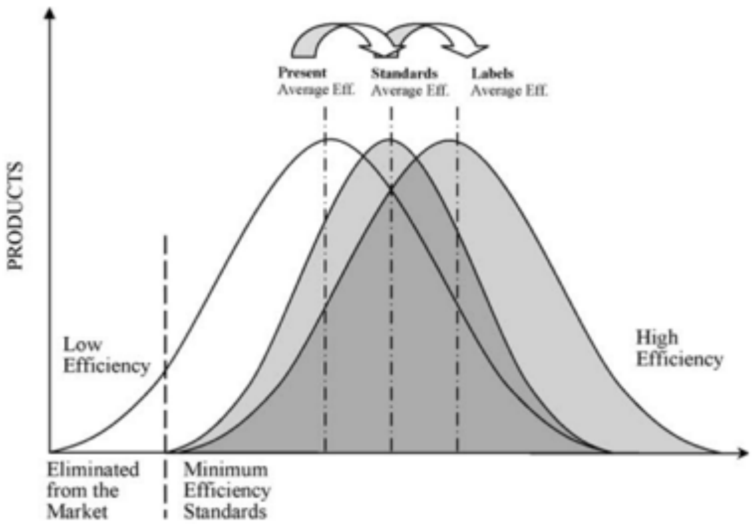

Fig. 2. Expected market transformation in product distribution with standards and labels [1].

Wiel and McMahon made evaluations on energy efficiency standards and energy labeling in household refrigerator products. The conceptual relationship between the number of unit sales and energy efficiency in household refrigerating products is given in Fig. 3 [12].

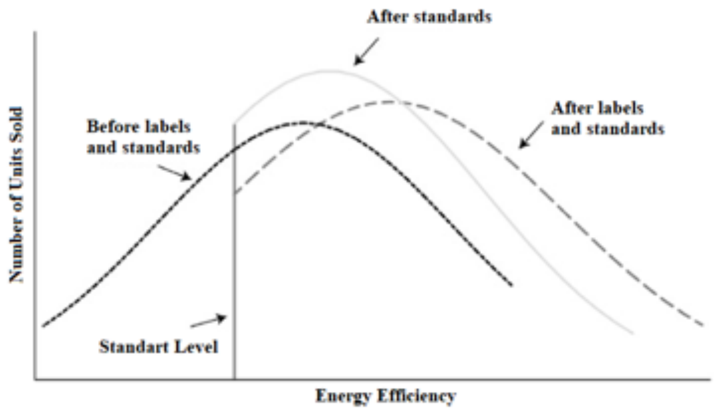

Fig. 3. Conceptually, the impact of energy efficiency standards and labels on the distribution of products in the market [12].

In refrigeration, demands are increasing for using environmentally friendly alternative refrigerants instead of R134a refrigerant, which has been widely used in the past years. In the literature research, various refrigerants that can be used as an alternative to R134a refrigerant in household refrigerators are R290 [13-16], R744 [13,17], R1234yf [13,14,18], R600a [14,18,19], etc. and various refrigerant gas mixtures [20-22].

The characteristics of R134a refrigerant and various alternative refrigerants are shown in Table 1 [13].

Table 1. Properties of alternative refrigerant gases [13].

Refrigerant	R134a	R290	R600a	R744	R1234yf
Normal boiling point [°C]	-26	-42	-12	-78	-29.4
Critical temperature [°C]	101	96.68	134.7	30.98	94.7
Critical pressure [kPa]	4059	4247	3640	7377	3382
Liquid density at 25°C [kg/m^3]	1207	492.1	549.9	705.1	1092
Vapor density at 25°C [kg/m^3]	32.37	20.64	9.123	242.8	37.94
ODP	0	0	0	0	0
GWP 100 years	1370	20	20	1	<4.4
Atmospheric lifetime [years]	13.4	0.041	0.016	>50	0.029
ASHRAE 34-Safety code	A1	A3	A3	A1	A2L

Flores and his team made evaluations about refrigerant gases in household refrigeration products. They stated that there is an improvement in the use of these refrigerants due to the positive effects of 4th generation gases (R600a, R290, etc.) on global warming compared to other refrigerants used. The evolution of refrigerants in household refrigeration products is given in Fig. 4 [23].

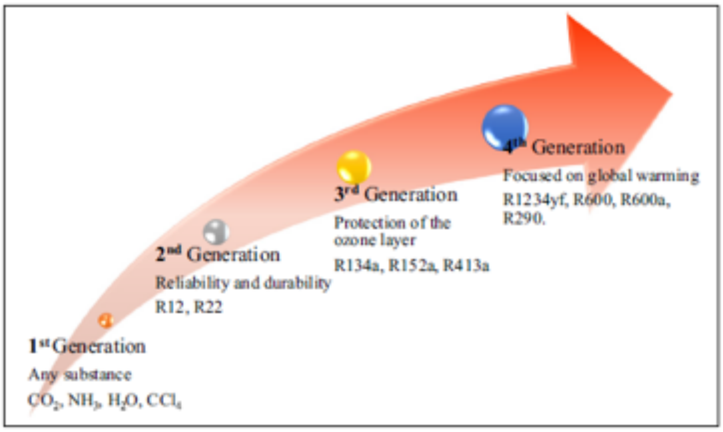

Fig. 4. Development of refrigerants in household refrigeration products [23].

Studies on energy performance in the commercial refrigerator sector are very limited. Jensen and his work group evaluated energy efficiency in the horizontal-type commercial refrigerator in line with compressor control strategies [24].

Three critical factors stand out for eco-design by Ma and his working group. In this context, they stated that in recent years, studies have been given to reduce the metal and plastic parts used in the refrigerator manufacturing phase and the energy consumption value in the usage process [25].

Within the scope of this study, the use of R290 refrigerant is important for compliance with the European Union regulations with a unique design in terms of obtaining energy efficiency and environmentally friendly features.

2. MATERIALS AND METHODS

2.1. Materials

The main body material AISI 304 was used to provide high strength for the innovative commercial refrigerator prototype, originally designed for the industrial kitchen sector. In line with the eco-design principles, the equipment forming the refrigeration (evaporator, compressor, fan, etc.) is brought together as a monoblock, enabling both the efficient cooling of the refrigeration chamber and the easy provision of necessary service.

2.2. *Methods*

Initially, eco-friendly designs of the innovative commercial refrigerator prototype were started. In particular, a monoblock design of the refrigeration group that allows easy assembly on the upper part of the prototype has been developed. Following the development of the designs, critical equipment for working with the new generation environmentally friendly refrigerant (hydrocarbon-containing R290) was selected appropriately. The innovative commercial refrigerator prototype and the refrigeration equipment's (monoblock) layout are given in Fig. 5.

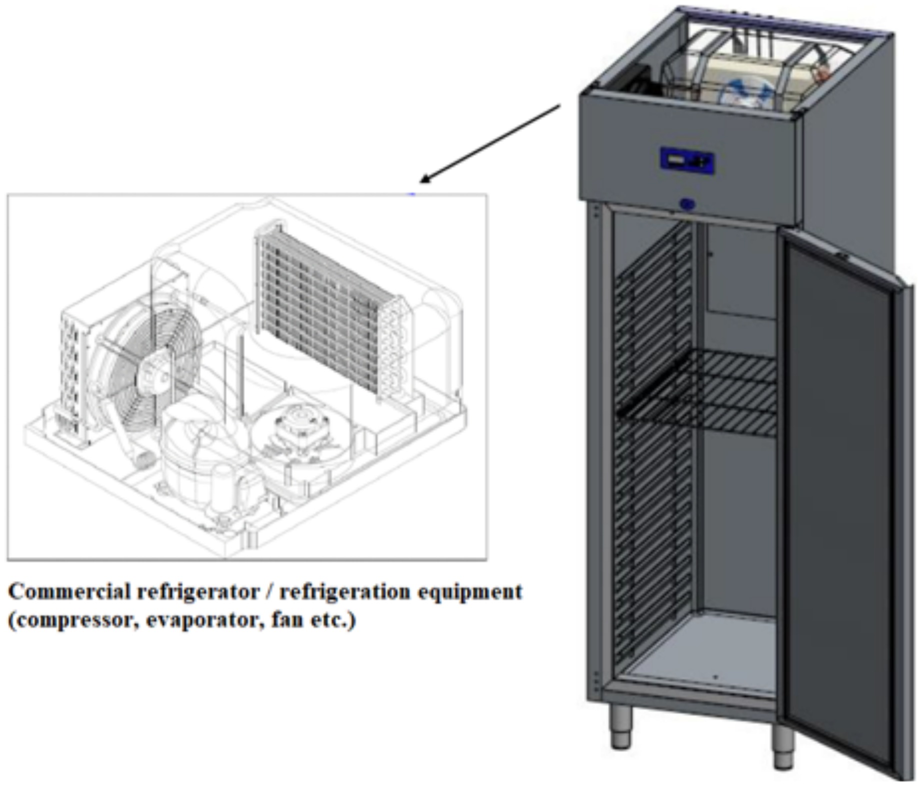

Fig. 5. The innovative commercial refrigerator prototype and the layout of the refrigeration equipment (monoblock).

The main features of the innovative prototype are also given in Table 2.

Table 2. Properties of the innovative commercial refrigerator prototype.

Body material	AISI 304
Operating temperature	-2/+8°C
Volume	1500x540x690 mm
Capacity	450 Liter
Electric Volt / Frequency	230 V – NPE / 50 Hz
Insulation thickness	80 mm
Insulation material	Polyurethane

Evaluations were made by ensuring that 2 pieces of commercial refrigerator prototypes were produced and measures were taken against the negativities that may occur during the test phase. A photograph of the test control units and test chamber for the innovative commercial refrigerator prototype is given in Fig. 6.

Fig. 6. Test control units and test room for innovative commercial refrigerator prototype.

The photograph of the test packages used to evaluate the cooling performance of the innovative commercial refrigerator prototype is given in Fig. 7. Test packages have different sizes as well as probe options.

Fig. 7. The photograph of the test packages (50x100x100 mm / 500 g.).

The composition of the test packs was prepared in accordance with the ISO 23953 standard, and the chemical composition of the test packs is given in Table 3.

Table 3. Composition of test packs.

Ingredient	Mass per 1 kg	%
Tylose	230 g	23
Water	764.2 g	76.42
Salt	5 g	0.5
Cresol (4-Chloro-m-cresol)	0.8 g	0.08

The photograph of the placement of the test packages in the evaluation process of the cooling performance in the commercial refrigerator prototype is given in Fig. 8. According to the test standard, wooden dividers are used between test packages.

Fig. 8. The test packages in the evaluation process of the cooling performance in the commercial refrigerator prototype.

3. RESULTS

The commercial refrigerator's cooling performance is made per the EN 16825 standard.

Refrigerating performance evaluations of the commercial refrigerator prototype were carried out at 40°C ± 1 (dry bulb temperature) and 40% ± 5 relative humidity as climate class 5 of the test room. A photograph of the test execution (door opening and closing) for the cooling performance of the innovative commercial refrigerator prototype in the climatic test room is given in Fig. 9.

Fig. 9. Door opening and closing in commercial refrigerator prototype test application.

According to the Energy Efficiency Index (EEI) data, the annual energy consumption value of the eco-friendly designed commercial refrigerator prototype has been calculated. While our standard product is in class D in terms of annual energy consumption value, it has been achieved to reach class A energy efficiency label value in terms of energy consumption value in the innovative prototype.

After the cooling performance tests, the photograph of the commercial refrigerator prototype with the high energy efficiency label (class A) is given in Fig. 10.

Fig. 10. Innovative commercial refrigerator prototype with high energy efficiency energy label.

4. DISCUSSION

Using environmentally friendly R290 gas instead of R134a refrigerant significantly contributed to the difference in annual energy consumption value. The change of the refrigerant alone is not enough to change the energy efficiency value to a large extent. In the process of using environmentally friendly refrigerants with original designs, changing various refrigeration equipment as well as the combination of the refrigeration group provides positive effects on increasing energy efficiency.

While the energy efficiency label application has been applied for many years in many household products (washing machines, air conditioners, vacuum cleaners, refrigerators, televisions, etc.), there is energy efficiency label application only in refrigeration group products (refrigerator and deep freezer) in commercial industrial products. Energy efficiency label applications of household and commercial products also differ according to various regulations.

5. CONCLUSIONS

In the industrial kitchen sector, energy labeling is a requirement solely for commercial refrigeration equipment such as refrigerators and freezers. Complying with various European Union regulations (2015/1094 and 2015/1095), commercial refrigeration products are categorized based on their energy consumption levels, and an energy label is affixed to the product. The outcomes of research conducted using systematic R&D approaches are outlined as follows:

- To enhance the environmentally friendly attributes in terms of carbon footprint, a hydrocarbon-containing R290 refrigerant has been adopted in place of the conventional R134a refrigerant.
- The innovative approach of consolidating refrigeration equipment into a single unit in the product design eliminates transportation losses and facilitates streamlined maintenance.
- Specific characteristics of refrigeration components (compressor, evaporator, fan, etc.) were determined to align with the eco-friendly refrigerant choice in the innovative prototype, ensuring efficient utilization.
- After creating the uniquely designed commercial refrigerator prototype and assessing its cooling performance using M packages (Tylose test packages) within the EN 16825 standard's testing phase, an impressive energy efficiency improvement of around 30% was achieved compared to the prevailing scenario.
- Before implementing the European Union's commercial energy labeling regulations, our standard commercial vertical refrigerator was categorized as class D. However, the distinctively designed commercial refrigerator prototype secured the highest energy label, class A, signifying superior efficiency.
- Following the refrigerating performance test, the commercial refrigerator prototype attained the highest-class A value, reaching 328.5 kWh per annum regarding energy consumption within the energy classification system.

These findings underscore the significant strides achieved through innovative design, eco-friendly refrigerant use, and adherence to energy efficiency standards. The study underscores the potential for substantial energy savings and enhanced sustainability within the commercial refrigeration sector.

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