Energy-efficient methods in meat product production

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Abstract: *This article analyzes energy-efficient innovative technologies in meat product production. Issues related to improving energy efficiency, modern cooling systems, heat pumps, digital monitoring, and the use of renewable energy sources are examined.*
Keywords: *energy efficiency, meat industry, innovative technologies, cooling systems, heat pumps, PEF, IoT, renewable energy*

The meat product manufacturing industry is considered one of the most energy-intensive sectors. In production enterprises, cooling, freezing, heat treatment, and logistics processes are major consumers of energy. In modern manufacturing, the increase in energy prices and the strengthening of environmental requirements compel enterprises to seek energy-saving solutions. Improving efficiency reduces product costs and also minimizes negative impacts on the environment.
In the meat industry, the largest share of energy consumption is related to cooling systems. Since these systems operate continuously, they consume a significant amount of electrical energy. Modern cooling systems based on ammonia (NH3) and carbon dioxide (CO2) are being implemented. These systems have high efficiency, consume less energy compared to traditional freon systems, and are considered environmentally safe.

Table 1.

Distribution of Energy Consumption

1	Cooling and freezing	40-50
2	Heat treatment	20-25
3	Mechanical processing	10-15
4	Auxiliary processes	5-10
5	Transportation	10-15

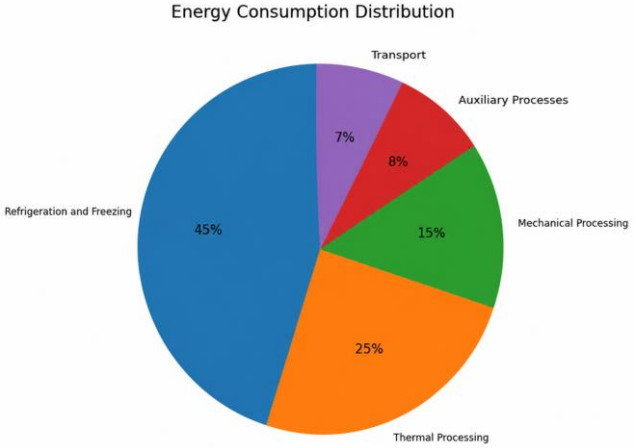

Figure 1. Distribution of Energy Consumption in Diagram Form

As shown in the diagram, the largest share of energy consumption belongs to cooling and freezing processes. Modernizing cooling systems is considered one of the most important directions for improving energy efficiency.

During product manufacturing processes, heat treatment causes significant energy losses. Heat pumps and heat recovery systems improve energy efficiency by reusing waste heat. These technologies are used for hot water preparation, steam generation, and other technological needs.

Ultrasonic and Pulsed Electric Field (PEF) technologies are considered highly effective in meat processing. These methods reduce heat treatment time, improve product quality, and decrease energy consumption. In particular, PEF technology makes it possible to inactivate microorganisms without the use of heat.

Table 2.

Efficiency of Performance

Technology	Main Function	Saving (%)
Heat Pump	Reuse of waste heat	30-60
CO2 sovitish	Environmentally friendly cooling and freezing	20-40
Impulsli elektr maydoni texnologiyasi (IEM)	Non-thermal microbiological treatment	20-30
Ultrasonik ishlov	Tenderizing meat structure	15-25
IoT monitoring	Real-time control and optimization	10-20

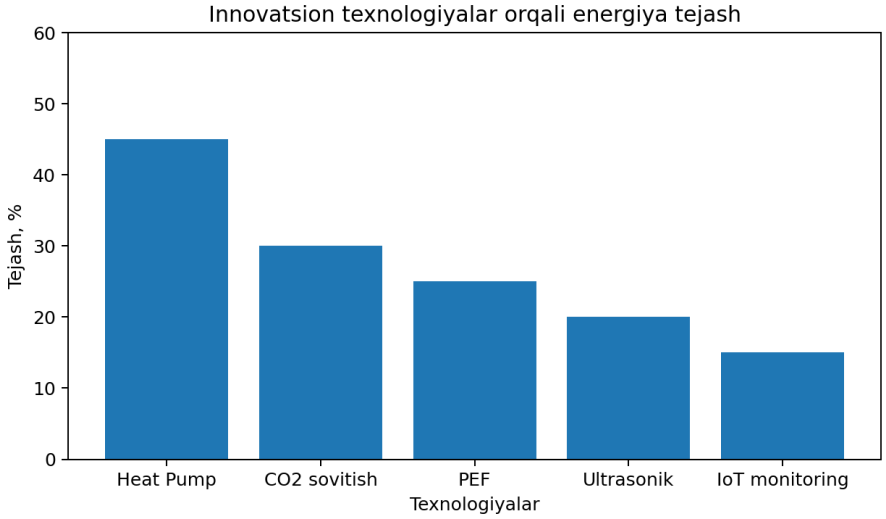

Figure 2. Level of Energy Saving Through Innovative Technologies

These indicators show that the comprehensive implementation of technologies can reduce production costs and improve the environmental efficiency of enterprises.

The use of renewable energy sources is one of the important directions. Through solar panels, biogas installations, and other sources, enterprises can independently cover part of their energy needs, thereby increasing production efficiency.

Strategies for improving energy efficiency include automation, energy audits, the implementation of modern equipment, and improving employee qualifications. Through a comprehensive approach, it is possible to achieve energy savings of up to 30-50%.

In conclusion, the implementation of energy-efficient technologies in the meat industry is of great economic and environmental importance.

The food production industry is one of the sectors that require substantial energy resources. Cooling, freezing, heat treatment, and logistics processes are the main consumers of energy. Today, rising

energy prices and increasing environmental requirements make the implementation of energy-saving technologies an urgent issue for enterprises.

In the meat processing industry, the largest share of energy consumption is related to cooling systems. Therefore, modern cooling systems based on ammonia (NH3) and carbon dioxide (CO2) are being widely used. These systems have high efficiency, consume less energy compared to traditional freon systems, and are environmentally safe.

Conclusion

The theoretical and practical aspects of implementing innovative energy-saving technologies in production processes were analyzed. As a result, it was determined that the meat industry constitutes one of the most energy-intensive industrial sectors.

Modern cooling technologies, including CO_2- and NH_3-based systems, significantly improve energy efficiency. Heat pumps and heat recovery systems enable energy savings of up to 30–60% through the reuse of waste heat.

Ultrasonic and Pulsed Electric Field (PEF) technologies have proven effective in reducing energy consumption while maintaining product quality.

Renewable energy sources ensure the sustainability of production and reduce waste. As a result, a comprehensive approach can achieve energy savings of up to 30–50%.

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