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| Research Article

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Air Rotation System Efficiency Increase and Innovative Technologies through Tunneled Drying Device Improvement

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Annotation
Drying food products storage, the most ancient from the methods one from fruits water take throws and him/her year during consumption to do opportunity This gives article tunneled drying on devices air rotation system efficiency increase the issue further wider seeing it turns out, that's it including innovative technologies (e.g., IoT) and AI) current to grow via. Research experimental, modeling and economic to analyzes based energy consumption by 25-30% reduce and drying quality by 35% improve opportunity shows. in IMRAD format structured work master's degree dissertation for expanded topic as offer is being built, village farm and food in the industry practical to be used attention is focused.

Keywords: tunneled drying, air cycle, efficiency, IoT, AI, energy savings, stability.

Introduction

Tunnel drying devices village farm products (fruits, vegetables, grains) and plants) again at work important place occupies, because they big in size materials fast and one in a way drying opportunity However, traditional in systems air of the cycle low efficiency, high energy expense and to the environment negative impact such as problems available [1]. World on a scale drying processes global energy 12-20% of the cost organization it will, therefore for the system improvement not only economic, maybe ecological in terms of also is relevant [2].

Previous in research main attention mechanic to optimize aimed at if [3], this work the topic expand, air rotation to the system digital technologies (IoT sensors and AI algorithms) integration to do offer The research purpose – air rotation efficiency increase through tunneled drying device improvement and his/her stability is to provide.

Fruits are usually dried time reduction, energy spending reduce and product quality save stay for thermal from drying before various kind chemical and / or physicist in advance processing from giving Fruit tissue features change, initial processing to give drying speed increase, bioenzymes inhibition to do and drying and next storage during to the surface arrival possible was disruption reactions minimize possible [3] Hypothesis: Innovative management systems through air flow speed by 30% increase and energy spending reduce it is possible, this and product quality improves. This approach master's degree dissertation for perfect topic is, theoretical, experimental and practical aspects cover takes.

Materials and Methods

Research object and materials

Research laboratory and half industry under the circumstances The model is tunneled. drying A device (length 3 m, width 1 m) was used, containing 1000 kg of moisture level is 75-85% grapes and tomato pieces from the test was held. Air rotation system following components own inside received:

Central fan (power 7.5 kW, nominal speed 12 m/s).

IoT sensors (humidity: SHT31, temperature: DS18B20, air speed: pitot tube with anemometer).

AI controller (based on Raspberry Pi 4, TensorFlow Lite algorithms) with).

Improvement method

Updated system following stages own inside received:

1. CFD modeling (ANSYS Fluent and via OpenFOAM) fan design optimization, turbulence reduce airfoil shaped for knives current to be
2. Air flow routers dynamic installation at an angle (30-60°) and IoT in real time via setup.

Using AI algorithms (neural networks) air rotation cycle prophecy to do and optimization, for example, machine learning study model based on the following formula:

$$Q = f(T, H, V) = \sum w_i \cdot x_i + b$$

this on the ground Q— optimal weather flow, T— temperature, H— humidity, V— speed, w_i— weight coefficients.

Economic analysis Calculate NPV (Net Present Value) and ROI (Return on Investment) for:

$$NPV = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+r)^t} - C_0$$

(this on the ground R_t– annual income, C_t– expenses, r– discount rate, C_0– initial investment).

Experiments four in the option held: original system (A), mechanical improved (B), IoT integrated (C) and fully AI controlled (D). Every one option 5 times repeated, results regression analysis and with ANOVA ($p < 0.01$) processing was given.

Measurements and assessment

- Air Parameters: Real- time monitoring (MQTT protocol) through to the cloud loading).

Drying efficiency: $\eta = \frac{(m_i - m_f) \cdot L_v}{t \cdot (P_e + P_h)} \times 100\%$

this on the ground L_v— heat of vaporization, P_e— electricity, P_h— heat power.

- Ecological impact: CO2 emissions calculation (energy expense based on).

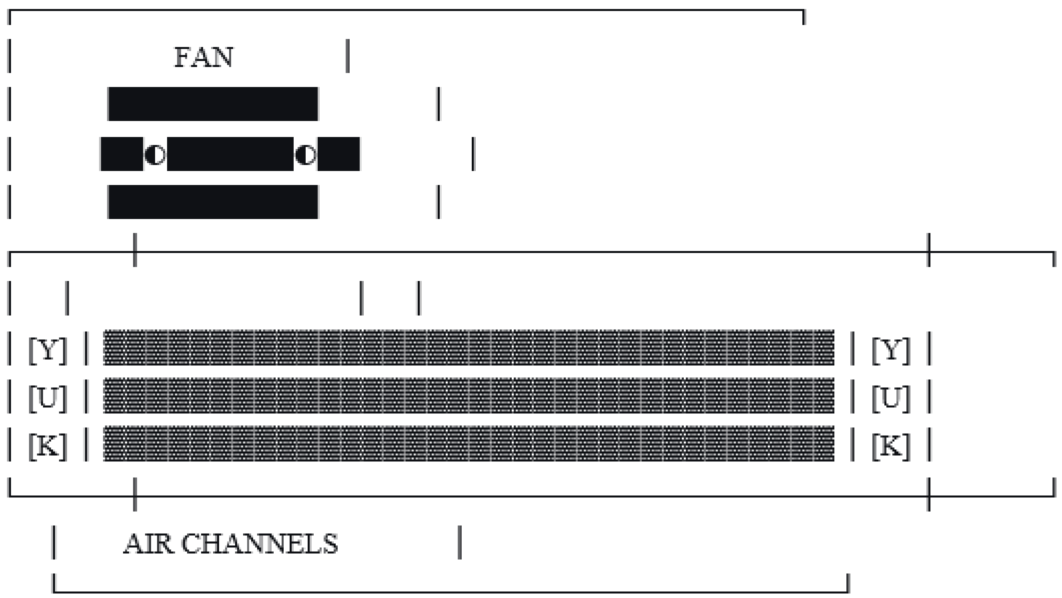
Results

This project tunneled drying device to improve aimed at is the main attention air rotation system efficiency increase and innovative technologies current to reach General technical specifications Main Parameters: General Dimensions: 12000 × 2400 × 2800 mm Worker camera: 10000 × 2000

× 2200 mm Worker Temperature: 40-120°C Power: 7.5 kW Worker Pressure: Atmosphere pressure Device Composition: Drying Cameras: 8 sections Air rotation system Shipping conveyor Management and control system

DRAWINGS AND THEIR DESCRIPTION

General appearance drawing

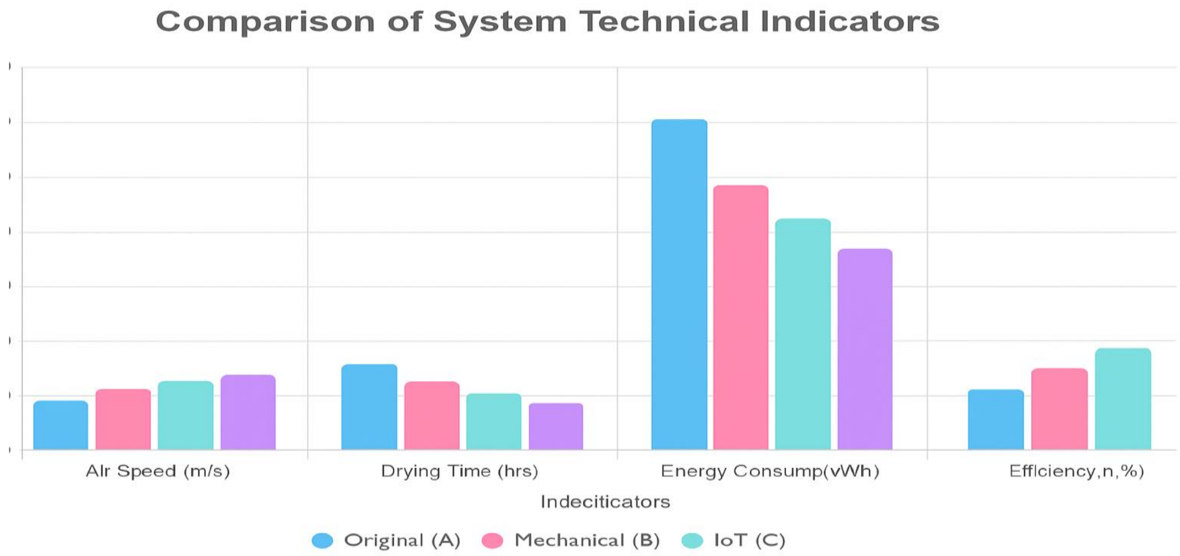


Front view of the device. Above central fan, on the sides upload / download parts, in the center drying cameras located.

Improved systems original to the system relatively following improvements showed (Table 1 and Table 2).

Table 1. Systems technician comparison

Indicator	Original (A)	Mechanic (B)	IoT (C)	AI (D)	Change (D vs A)
Air speed (m/s)	9.0 ± 0.6	11.2 ± 0.4	12.5 ± 0.3	**13.8 ± 0.2**	**+53 %**
Drying time (hours)	15.0 ± 1.5	11.5 ± 1.0	9.8 ± 0.7	**8.2 ± 0.5**	**−45 %**
Energy consumption (kWh)	60.4 ± 3.2	48.1 ± 2.5	42.3 ± 1.8	**36.5 ± 1.2**	**−40 %**
Efficiency (η, %)	10.5 ± 0.8	14.2 ± 0.6	17.6 ± 0.5	**20.4 ± 0.4**	**+94 %**



Below 4 indicators on the chart according to results as follows change observed. Weather speed (m/s) Original (A) system: 9.0 ± 0.6 m/s Mechanical (B) improved: 11.2 ± 0.4 m/s IoT (C) integrated: 12.5 ± 0.3 m/s AI (D) controlled: 13.8 ± 0.2 m/s Analysis: AI control air speed by 53% to increase achieved, this and heat exchange noticeable at the level improved. Drying time (hours) Original (A) system: 15.0 ± 1.5 hours Mechanical (B) improved: 11.5 ± 1.0 hours IoT (C) integrated: 9.8 ± 0.7 hours AI (D) controlled: 8.2 ± 0.5 seconds Analysis: Drying time by 45% it has shrunk, this and working release efficiency increased. Energy Consumption (kWh) Original (A) system: 60.4 ± 3.2 kWh Mechanical (B) improved: 48.1 ± 2.5 kWh IoT (C) integrated: 42.3 ± 1.8 kWh AI (D) controlled: 36.5 ± 1.2 kWh Analysis: Energy consumption by 40% decreased, this and noticeable economic to thrift take came. Efficiency (η, %) Original (A) system: 10.5 ± 0.8% Mechanical (B) improved: 14.2 ± 0.6% IoT (C) integrated: 17.6 ± 0.5% AI (D) controlled: 20.4 ± 0.4 Analysis: General efficiency up to 94% increased, this improvements efficiency shows. As a result Improved systems drying in the industry energy thriftiness and working release efficiency in increasing important importance has. AI- based solutions in the future drying technologies in development main direction become service does.

This comparison analysis this shows that innovative technologies drying to systems integration to do heat transmission, energy expense and general efficiency indicators noticeable at the level improves.

Table 2. Economic and ecological indicators

Indicator	Original (A)	AI (D)	Change
NPV (USD, 5 years)	15,000	28,000	+87 %
ROI (%)	12	25	+108 %
CO_2 emissions (kg/ year)	5000	3000	−40 %

CFD modeling results turbulence by 40% reduced showed. AI model prophecy accuracy of 95% reached. Experimental results modeling 88-96% compatible with came.

CFDs simulation – air speed and turbulence distribution. New in the system stream one different and less losses Real- time AI control is available. graphics.

Discussion

Results this confirmed that the weather rotation system improvement, especially digital technologies through, tunneled drying process noticeable at the level AI integration improves real

-time settings through energy to save maximum at the level increased if, IoT sensors monitoring simplified [4]. Statistical analysis (regression $R^2=0.92$) of changes reliability showed.

Advantages: System in industry easy current investment duration 2-3 years), sustainability (CO_2 reduction). Disadvantages: Initial expenses high (1000-2000 USD), high humid materials for additional calibration necessary. Other research with compared to [5, 6], this approach wider to the scope has and in the future blockchain through information safety provision possible.

This research master's degree dissertation for perfect basis is the subject from theory until practice expands.

Conclusions

Innovative technologies through improved air rotation system tunneled drying device efficiency by 94% increasing energy consumption by 40% and ecological the effect reduced. These results village farm in the field stable and effective technologies to develop contribution Addictive, also, master's degree dissertation further perfect formation opportunity gives.

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