# Banana Dryer with Temperature and Time Control for Small and Medium Industries

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### Abstract

*Pisang Salai* is one of the famous dishes in the state of Johor because of its unique taste. The drying process is the main process in the production of *pisang salai*. Therefore, to ensure that the quality of *pisang salai* is not affected, the drying process of bananas must be carried out correctly. However, when the monsoon season arrives, the drying process will be affected due to the lack of light sources from the sun. Therefore, entrepreneurs want a new alternative that does not need to depend on light sources from the sun. In the development of this project, there are three main objectives, namely, designing, developing, and testing in terms of usability and functionality of the prototype to be developed. The purpose of this project is to help entrepreneurs overcome the problems that they faced. The Design Thinking model was chosen as a guideline throughout the prototype development process. An Arduino ESP32 microcontroller is used as a controller unit to control the system. In addition, the Blynk application is also used to further expand the use of IoT to the public. If this product can be brought to market, it can also simplify things for those who operate *pisang salai*.

## 1. Introduction

The Malaysian Small and Medium Industries (SMIs) sector is primarily concerned with the manufacturing of smoked banana chips. Small-scale industries (SMIs) are those that are run independently of large corporations, have fewer than 150 employees, and have annual sales of less than RM 25 million (SME Corp. Malaysia, 2015). In SMIs, smoked banana chips are a well-liked product, and choosing ripe bananas is essential to making them (SME Corp. Malaysia, 2018). The focuses of this study are on the difficulties faced by SMIs in business, especially how Malaysia's equatorial climate affects the custom of using sunlight to dry banana chips.

This study highlights the necessity of ergonomic innovation as a solution to these problems. The purpose of this section is to introduce a specially designed machine that has an electronic system to address the limitations of using sunlight for drying in inclement weather. According to sources from the Malaysian Meteorological Department (2023), the southwest monsoon starts in May until September while the northeast monsoon starts in November until March. This device is designed to make the process of drying banana chips more efficient, providing SMIs business owners with a workable option. The incorporation of contemporary technology, like the Internet of Things (IoT), enables automated control and guarantees the bananas' ideal smoking conditions. Overall, the innovation seeks to support the sustainability and prosperity of SME entrepreneurs in Malaysia by improving efficiency and removing weather-related barriers in the small and medium industry sector.

## 1.1 Background of Study

The important drying procedure that is used in Malaysia's Small and Medium Industries (SMIs) to produce smoked banana chips is covered in the text. The quality, texture, flavour, and shelf life of the smoked banana chips must all be preserved, and mould growth and spoiling must be avoided through careful drying. However, the drying process is susceptible to disruptions due to unpredictable weather changes in Malaysia, a country experiencing two seasons - hot and humid (Hamid, 2012). Temperature is identified as a critical aspect in controlling foodborne diseases, as stated by the Ministry of Health Malaysia (2019). The challenges faced by SMIs business owners are highlighted in the text, along with the significance of timing during the drying process and the effects of weather variations. Based on the researcher analyzed, the average humidity throughout the year in this region. According to Weather Spark (2023), the temperature in Parit Raja varies from 73°F to 90°F throughout the year.  In order to help entrepreneurs, particularly in areas like Parit Simpang Sikon, Parit Raja, Johor, where the study was conducted, it presents the idea of creating a drying machine with temperature monitoring capabilities. The machine's objectives are to improve the quality of smoked banana chips, increase the effectiveness of the drying process, and solve humidity-related problems in the surrounding environment.

## 1.2 Problem Statement

High temperatures, extended periods of time, and increased humidity from rain can negatively impact the production of smoked banana chips because of problems that arise during the bananas' drying process. The shelf life, texture, flavour, and quality of the smoked banana chips are all negatively impacted by prolonged drying times and erratic temperatures. Furthermore, it is not feasible to use only conventional drying techniques when it is raining. Using an oven heater helps keep the temperature at ideal levels while drying bananas quickly. Furthermore, the choice of suitable drying temperatures and times affects the final quality of the bananas produced. According to Suhaimi (2018) claims that compared to conventional methods, using an oven heater can result in smoked banana chips that are higher-quality, crispier, and more colourful. Thus, an IoT for Small and Medium Industries (SMIs) prototype machine for drying smoked banana chips will be developed.

## 1.3 Research Objectives

The development of this prototype is aligned with the specified objectives:
    i. Designing a prototype for banana drying using IoT for small and medium industries.
    ii. Developing a prototype for banana drying using IoT for small and medium industries.
    iii. Testing the usability and functionality of the prototype for banana drying using IoT for small and medium industries.

## 2. Methodology

According to Balamuralithara (2018), the Design Thinking model is a tool that can improve problem-solving, creativity, innovation, empathy, and critical thinking. The researcher has decided to use the Design Thinking model in the development of the prototype for the Banana Dryer with Temperature and Time Control for Small and Medium Industries. This choice is supported by the model's inclusion of components like empathy, define, ideate, prototype, and test, which are thought to be appropriate for helping to streamline and facilitate the process of developing prototypes.

## 2.1 Research Design

This model has five key phases: emphatize, define, ideate, and prototype. These phases are listed in the order they appear in the model.

a) Emphatize
An interview survey was conducted with the Small and Medium Industry (SMIs) entrepreneur, Mr. Mohamad Shahridzal bin Basri, on May 23, 2023, Tuesday, at 4:30 in the afternoon at Parit Simpang Sikon, Parit Raja,

Johor. The diagram below illustrates the questions and answers from the interview using the 5 Why Analysis method.

Table 2.1: Information obtained from interviews.

| No | Question | Answer |
|---|---|---|
| 1. | How long has this smoked banana production been operating? | 3 years. |
| 2. | What type of banana is used? | Pisang kapas because the smell and sweetness of the banana is natural. |
| 3. | What method is used for drying bananas? | Placing bananas under the sun. |
| 4. | How is the drying process done in the rain? | Entrepreneurs will dry bananas by placing them in smoke house (*sabak*). |
| 5. | How long does it take to dry bananas? | Around 2-3 days. |
| 6. | Does climate change affect the banana drying process? | Affects if the rain continues for 3-5 days. |
| 7. | What other problems are encountered during the drying process? | '…..the rain is slow to dry…..'' '…..heat / inconsistent temperature …..' '…..just put under the sun …..' '…..a lot of bananas, the drying process is slow …..' |

b) Define

This second phase is a result of the information obtained and the analysis conducted in the first phase. Additionally, the researcher also examines existing products in the market from various aspects to determine the effectiveness of the prototype to be developed. The diagram below illustrates key words that be concluded from the interview.

Table 2.2: Problems obtained from the interview session.

| No | Key Word | Problem |
|---|---|---|
| 1. | • Drying | - Using the traditional method. that is placing bananas under the sun. |
| 2. | • Temperature <br> • Quantity of bananas | - The temperature is bot consistent. <br> - The production of smoked banana interrupted when the drying process is affected. |
| 3. | • Raining <br> • Humidity | - Requires a long period for the drying process. <br> - Bananas will quickly rot and the quality of bananas will be affected. |

c) Ideate

The researcher's primary goal is to create a prototype that helps entrepreneurs in the Small and Medium Industry (SMI) industry solve their problems. In this phase, the researcher can generate creative ideas through brainstorming methods to design an innovative prototype for the Banana Dryer with Temperature and Time Control for Small and Medium Industries. The flexible, durable, and user-friendly nature of the developed prototype should also be guaranteed by the design specifications. In order to prevent electrical leaks, the researcher must also make sure that the prototype has high design resilience and safety during this phase. Therefore, there are several things that should be considered, including:

    i.  Model sketch
    ii.  Size and shape of the prototype
    iii.  Cost
    iv.  Color
    v.  Selection of tools and materials
    vi.  Operating circuit
    vii.  Selection of hand tools and machines

d) Prototype

The researcher must develop a prototype based on the Ideate phase. In this phase, there may be possibilities for improvements from various aspects. Therefore, the researcher must ensure that the developed prototype functions as designed. Additionally, the researcher should ensure that each step of the process is carried out systematically to ensure the smooth development of the prototype. The following is a 3D design sketch that has been selected by the researcher.
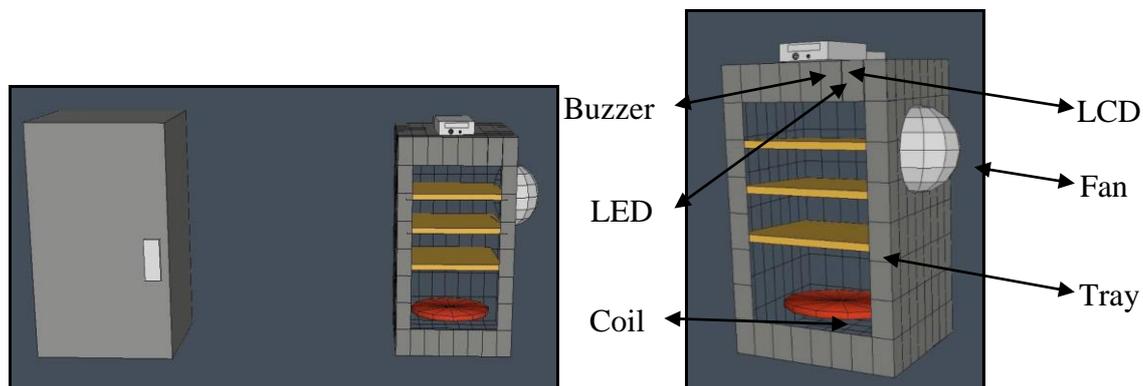
**Fig. 1** *3D prototype design and components used*

## 2.2   System Development

In this project, the Arduino ESP32 module serves as the main component responsible for controlling, processing information, and providing instructions to other components to operate based on predefined code instructions. Among the other components involved in ensuring the smooth operation of this system are the Arduino ESP32, temperature sensor, LCD display, buzzer, relay, and heating coil. Furthermore, the Arduino IDE software is utilized to develop the system's control by creating corresponding code instructions, including:

a) Establishing a Wi-Fi connection on a mobile phone to activate the ESP32 module.
b) Turning on the circuit connection for the relay and heater.
c) Detecting the ambient temperature.
d) Displaying temperature readings on the LCD.
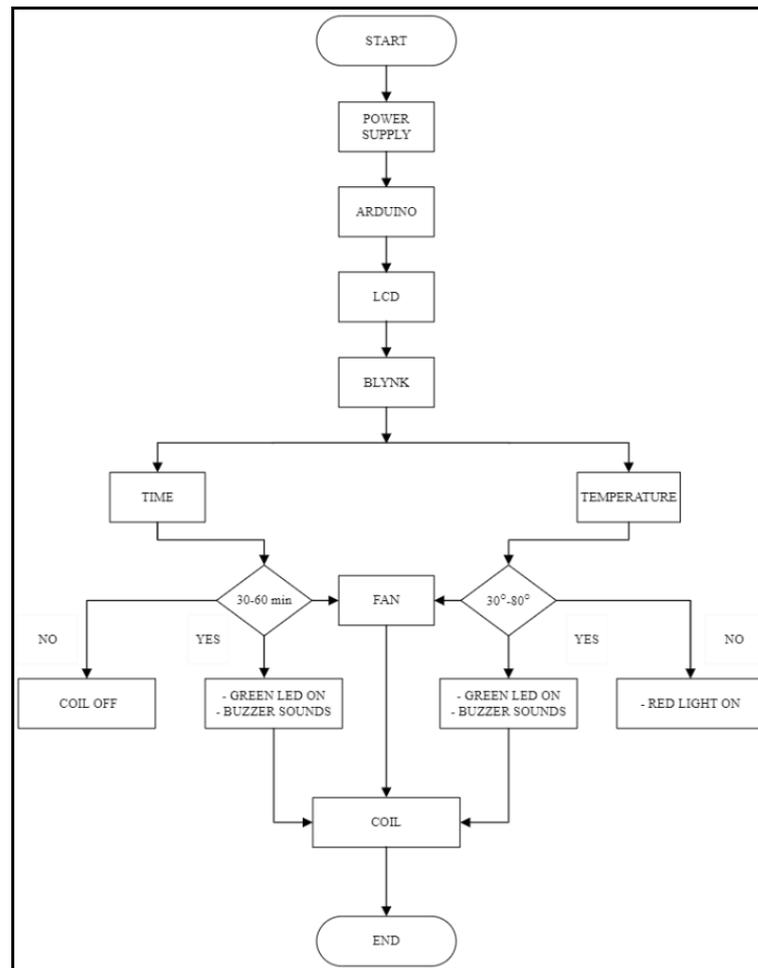e) Activating the LED and buzzer as indicators based on the control instructions.

**Fig. 2** *System operation flow chart*

The diagram above illustrates the clear and comprehensive operational flowchart with each component used. Each component will be connected to the Arduino ESP32 module based on the designed and specified connections. Each control for these components has its own set of code instructions. In this system, the thermocouple temperature sensor functions to detect ambient temperature readings. When the sensor obtains temperature readings at the maximum level, the relay will be deactivated for a while and will resume operation once the temperature readings reach the maximum level again. During the heating process, the green LED will light up, while the red LED will illuminate if the ambient temperature exceeds the specified level. The LCD display will show the temperature readings detected by the sensor.
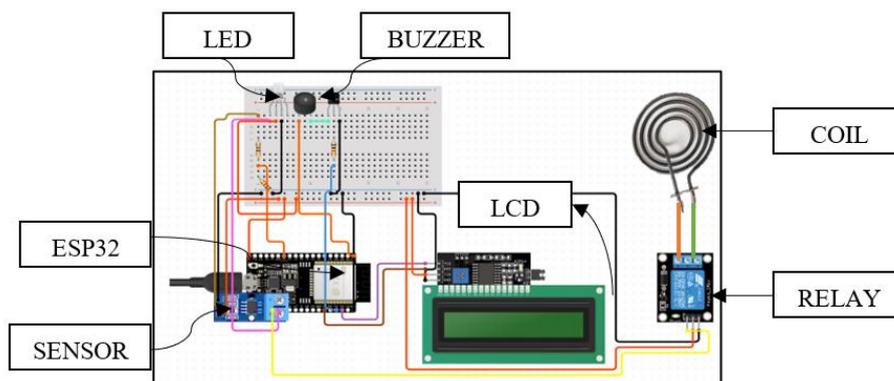
## 2.3  Circuit Developement



**Fig. 3** *Schematic circuit of the system*

## 3. Results and Discussion

The results and discussion section presents data and analysis of the study, from the experiment that has been conducted to the Banana Dryer with Temperature and Time Control for Small and Medium Industries.

## 3.1 Results

a) Component Testing
In order to ensure the objective of the functionality of the prototype developed successfully, an analysis of the components used was carried out. The purpose of this analysis is to ensure that the operating system for banana drying runs smoothly. The table below shows the results of testing the components.

**Table 1** Component functionality testing results

| Component | Testing | | |
| --- | --- | --- | --- |
| | 10 min | 20 min | 30 min |
| Timer | / | / | / |
| Thermocouple | / | / | / |
| Heating coil | / | / | / |
| Relay | / | / | / |
| Fan | / | / | / |
| LCD display | / | / | / |
| Arduino ESP32 | / | / | / |
| Buzzer | / | / | / |
| Blynk apps | / | / | / |

b) Time period and temperature

Based on the analysis conducted the drying process is scheduled to last 30 minutes, and temperature readings are taken every 10 minutes. The results obtained indicate that the higher the set temperature, the shorter the required time. It can be shown that using this prototype speeds up the drying process in comparison to using the older sun-drying method. Additionally, the type of banana used also plays a role because the thickness of each banana varies. The diagram below provides graph and evidence of the condition of the bananas before and after drying.

**Table 2** Analysis and results for time

| Item | Time | Unit |
| --- | --- | --- |
| 1 | 5 | min |
| 2 | 10 | min |
| 3 | 15 | min |
| 4 | 20 | min |
| 5 | 25 | min |
| 6 | 30 | min |

**Table 3** Analysis and results for time.

| Item | Temperature | Unit |
| --- | --- | --- |
| 1 | 50 | °C |
| 2 | 47 | °C |
| 3 | 44 | °C |
| 4 | 40 | °C |
| 5 | 33 | °C |
| 6 | 26 | °C |
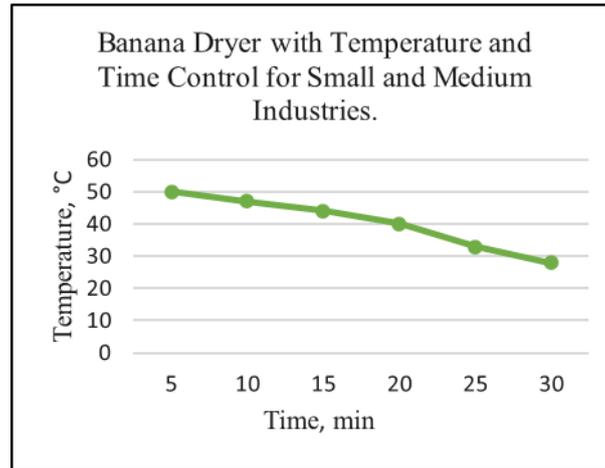
**Fig. 4** *Graph of the result of temperature versus time*

| System view in Blynk apps | Explanation |
| --- | --- |
|  | 1. Bananas condition before drying.<br><br>2. Bananas looks thick and juicy. |
|  | 1. Bananas condition after drying.<br><br>2. Bananas become dry and shrink. |

**Fig. 5** *Drying*

The significant difference between the conditions of the bananas is in terms of the size and shape of the bananas. The size of the banana after drying will shrink. Finally, as a result of the drying process carried out, it can be proven that the development of this prototype can work effectively.
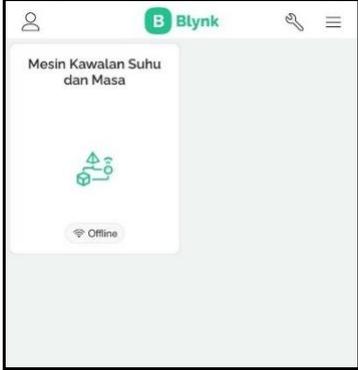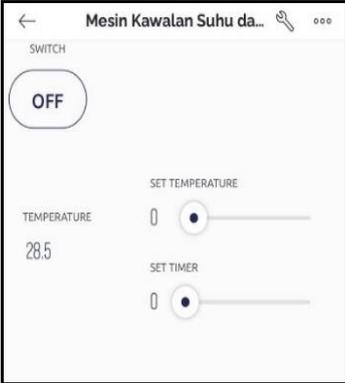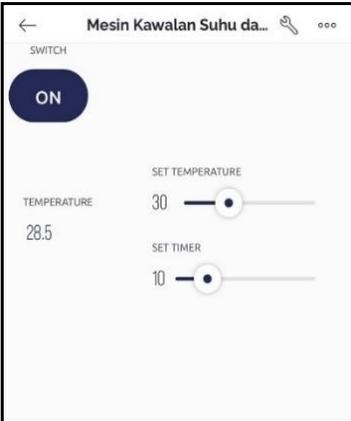
c) Blynk applications system

| System view in Blynk apps | Explanation |
|---|---|
|  | 1. Connect your mobile phone to the system using Wi-Fi/hotspot. Next, press the display that reads *Mesin Kawalan Suhu dan Masa.* |
|  | 2. Ensure the switch is in the OFF position, and both temperature and time are set to 0. |
|  | 3. Next select the desired time and temperature, then press the ON button on the Blynk display to active the system. |

**Fig. 6** *Apps*

## 3.2 Discussions

In summary, the development of the Banana Dryer with Temperature and Time Control for Small and Medium Industries has been successfully completed after thorough testing and evaluation. Comprehensive testing was conducted on all components utilized in the system to ensure its functionality. The developed system underwent an evaluation process to verify compliance with specified specifications and to identify areas for improvement in the future. Potential weaknesses such as technical issues with IoT applications, prototype size, or challenges with data analysis were identified, and ongoing testing and development are essential to address these issues and enhance system effectiveness and efficiency. Despite potential weaknesses, the project offers numerous

advantages that can improve efficiency. In summary, the Banana Dryer with Temperature and Time Control for Small and Medium Industries using IoT holds promise for enhancing the banana drying process and aligning with the study's objectives.

### 3.2.1 Designing a prototype for banana drying using IoT for small and medium industries

After analyzing the data, the prototype of the temperature and time control machine for the banana drying process was successfully developed according to the design, size and measurement as discussed. To design this prototype, the first step that needs to be done is to make a sketch drawing. This aims to ensure that researchers can provide various ideas during the design process. As a result of the sketch, then the researcher can choose the appropriate design to develop. Systematic design methods in product development can produce products that are able to solve user problems, (Jalil, 2001). Therefore, the process of designing the prototype of the temperature and time control machine started by drawing some preliminary sketches using Autocad and 3D Modeling software. In addition, the sketched design must be compatible with the circuit that will be used in the development of the system.

Next, the collection of data and information related to the product is the most important element before developing a product. Among the information obtained is about the comparison of existing products with products that want to be developed. According to Sundin Lindah & Ijomah (2019), creative machine design can result from creative thoughts and ideas. Therefore, the results of the analysis related to the design of the prototype are also stated. The results of the analysis obtained from the experts show that the design of the prototype is suitable to be developed and the first objective has been successfully achieved.

### 3.2.2 Developing a prototype for banana drying using IoT for small and medium industries

The second objective pertains to the development of the control system for the prototype. As stated, the Arduino ESP32 is utilized as the microcontroller to provide and control instructions in this project. Therefore, careful selection of programming language or code instructions is essential to ensure that the system functions and controls effectively. Additionally, the Arduino ESP32 offers easier and clearer programming compared to other software, and the components are readily available (Ilham, 2014). Hence, the researcher prefers using Arduino software as the microcontroller system capable of controlling the entire system compared to the Arduino Uno used by researcher 2 based on the past case study for the automatic dried fish dryer machine (Afini, 2018).

Furthermore, the developed system is used to control several output components. Among the controlled components are the LCD display, temperature sensor, relay, LEDs, and fan. The use of the fan is to ensure that the temperature remains stable and constantly moving. Additionally, the circuit storage space needs to be separated from the prototype casing to prevent electronic components from damage and exposure to generated heat. The heating element used is a coil type. This type of heating element is highly effective in generating high heat as it can produce up to 5 kW of power. Furthermore, the use of coil-type heating elements is more efficient compared to LED lights based on a past study conducted by UTHM student (Hanipah Binti Seman, 2018). Based on the analysis confirmed by the experts have stated that the developed control system operates well. However, the heating element used is not suitable because the generated heat is not consistent. Nevertheless, the second objective has been achieved, but improvements are needed in the future.

### 3.3.3 Testing the usability and functionality of the prototype for banana drying using IoT for small and medium industries

The final objective to be achieved by the researcher is regarding the usability and functionality of the banana drying prototype using IoT for small and medium industries. However, usability and functionality are two different elements. Usability refers more to whether the developed prototype is easy to use and beneficial to users, while functionality refers to the performance of each component related to the developed system for this prototype.

Drying is a process to reduce the moisture content in a material (Madson, 2017). The heating element used is a coil type with a power rating of 5 kW. Therefore, the heat generated by the heater is better than in previous studies. Additionally, the drying process time is also faster compared to previous studies. Based on the

analysis results from experts, all experts unanimously stated that overall, the usability and functionality of the developed prototype can be well-controlled, and the third objective has been successfully achieved. Lastly, the banana drying prototype developed in this study has its own advantages. Its advantages include the ability to control time and temperature using a smartphone. The Blynk application is used as an intermediary to power the prototype system. Additionally, it can also detect ambient temperature to facilitate users in setting the appropriate temperature for the drying process.

## 4. Conclusion

The successful development of the banana drying machine prototype with temperature and time control for small and medium industries using IoT has fulfilled its objectives. The careful planning, guided by the Design Thinking model, ensured a systematic design process with creative input. The prototype's usability and functionality were positively evaluated through testing and expert validation, affirming that the chosen temperature and time settings, as well as the coil-type heating element, effectively contribute to the banana drying process. The developed system aligns with the specified design criteria, achieving its objectives and demonstrating its potential to enhance efficiency in banana cultivation and drying processes for small and medium-scale industries.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contribution to the paper as follows:* **study conception and design:** *Nurul Atirah Abd Razak, Alias Masek;* **data collection:** *Nurul Atirah Abd Razak;* **analysis and interpretation of results:** *Nurul Atirah Abd Razak, Alias Masek;* **draft manuscript preparation:** *Nurul Atirah Abd Razak, Alias Masek. All authors reviewed the results and approved the final version of the manuscript.*

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