Drying fresh cassava chip using biomass energy with IoT monitoring system

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Abstract: The main purpose of this work is to build a biomass dryer using coconut shells with a remote monitoring system for drying any kind of cracker raw materials, especially cassava chips. Remote monitoring has utilized the internet of thing (IoT) concept, which recording temperature, relative humidity, and relative moisture of the object inside the dryer. The dryer can be loaded with three shelves simultaneously. Raw material for cassava crackers with a total mass of 10 kg. The raw material for cassava crackers is placed in the Biomass drying chamber. The raw material for cassava crackers is dried within two hours. The loss of moisture content of all raw materials for cassava crackers increased with increasing drying time and temperature. It is recommended to use drying system with utilize IoT system as remote monitoring system because it will save in time and employee, as well as minimize human contact in the new normal condition because of Covid-19 pandemic.

Keywords: cassava, drying, biomass energy, IoT, new normal

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1 Introduction

Cassava chip is famous food in many countries as a crispy and crunchy snack. The fresh cassava as raw material needs to be dried condition for longer preservation and ease in processing. Currently, the demand for crackers made from cassava continues to increase along with the increase in population and the number of recreational areas in Indonesia. The total harvested area of cassava in Riau province is 1,413 hectares with the total production of cassava in 2018 is 133,783 tons (Diskepang, 2019). This abundant cassava yield is a potential raw material that can be used for making cassava crackers as processed food. Most of the natural food drying methods are barely able to deliver the product to the desired specifications due to adequate hygienic conditions (Hnin et al., 2018; Villalobos et al., 2019). Moreover, the drying process carried out with conventional fuels with a closed system has a high cost (Udomkun et al., 2020). Because of that, it is necessary to look for a drying system that is more hygienic and environmentally friendly and uses an IoT system which is very suitable for the current pandemic conditions, because the IoT system will reduce contact between workers (Khubrani and Alam, 2021).

According to Okeke et al. (2018) in less developed countries there has been a decrease in the percentage of food loss due to spoilage by 25% and 40%, respectively. Joardder and Masud. (2019) stated that the most developing countries still depend on traditional food preservation method, such open sun drying, salting, smoking, and cooling method. The cold storage method where the foodstuffs will be stored in a highly refrigerated room thereby increasing small-scale farmers to meet the sudden and high demand of the market without significant wastage. This method is expensive and small-scale farmers cannot afford it. Meanwhile,

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salting and smoking method cannot be implemented for the most agriculture products. The drying method is the most appropriate solution to reduce spoilage, extend shelf life and increase the market value of the product, because it can be processed into food products that are more economically valuable, thus enabling poor small farmers to earn profits.

The drying technique has been carried out by many previous researchers, including Taseri et al. (2018) who have used a heat pump closed loop drying mechanism at different air velocity and temperature levels to dry grape pomace which was able to reduce the drying time by 69% compared to natural drying. The results of the research show that characteristics such as color and quality do not change with this drying system, meaning that such drying systems can be used for industry efficiently (Hasan et al., 2019).

Drying ovens are basically closed structures that trap heat radiation resulting from burning coconut shell waste biomass, to create a favorable microclimate for higher productivity. Various researchers have studied drying for foods (Sun et al., 2019). Research on drying vegetables and fruits has been carried out, such as peppers (Azaizia et al., 2020), garlic (Hadibi et al., 2021), tomato (Mohsen et al, 2019), and kiwi fruit (Ozgen and Celik, 2019) using solar thermal and electric oven has been reported by many researchers (Ajala et al., 2019; Warji and Tamrin, 2021; Sandra et al., 2021).

The main problem in the business of drying agricultural products is the sustainability of energy sources. On another side, the demand for quality dry agricultural products at low prices is greatly intended by everyone, especially those in the agricultural product processing industry (Lamidi et al., 2019). The drying rate is strongly influenced by the type of material to be dried, the temperature in the drying room, and the humidity of the air in the drying chamber (Babu et al., 2018). Based on the results of the study that the less volume of material to be dried, the shorter the drying time. Drying performance by a device is strongly influenced by the water content in the material, product geometry, and physical features of a material. The above can affect the cost of drying an agricultural product.

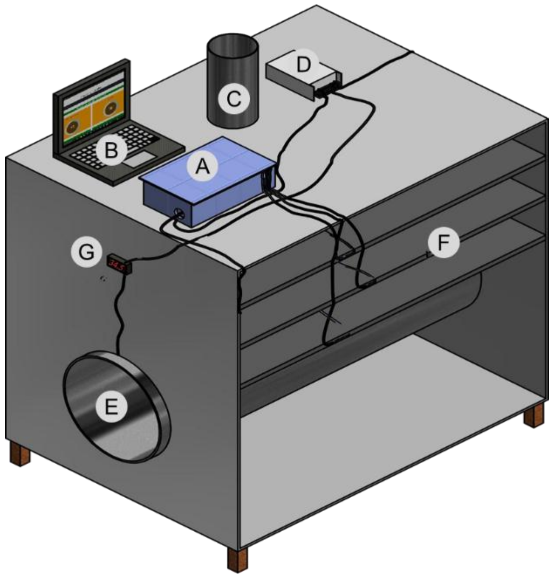
The drying method with coconut shell waste biomass energy can be used to dry agricultural products such as cassava (Muhammad, 2021). Cassava harvested in tropical conditions will have a high water content ranging from 56% to 67% so that it is very easy to experience post-harvest damage (Nayak and Bhushan, 2019). This is because the dryer will increase the temperature and reduce the moisture content in the material and reduce drying time (Nukulwar and Tungika, 2021). The results of research conducted by Taşeri et al. (2018), the difficulty in a drying process is controlling the quality specifications of the final product. The drying method is carried out in a closed room, so it can control the drying parameters well and get a more hygienic product that will be accepted by consumers. With the current Covid 19 pandemic condition, it is clear that this adds to the problem for farmers, so this research will try to provide a solution by implementing an IoT system in the post-harvest drying process.

The main purpose of this work is to make post-harvest drying technology based on biomass energy from coconut shell waste using IoT system for drying cassava crackers. This research will study the characteristics of the moisture loss, temperature, and humidity of fresh cassava chips under biomass dryer. Cassava drying technology based on coconut shell biomass waste energy with the IoT system is very suitable to be done, because it can increase the lifespan of an agricultural product, and can prevent damage to cassava raw materials.

2 Materials and methods

This research was conducted at the Earth Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, Riau University, Pekanbaru-Indonesia. The geographical position of the laboratory located at 0.4775 N, 101.3758 E. The implementation of this research will record the results of measuring air temperature and humidity and water content digitally and connected to the IoT system. Figure 1 shows a post-harvest dryer technology tool based on biomass energy with an IoT system.

The fresh cassava of a moisture content is about 63% (w/w) and should be preserved under 8% water content to avoid a rot condition (Ajala, 2020). Cassava is sliced in circular geometry with a uniform thickness of about 5 mm. The cassava slices are placed on the surface of the shelf, then 0.5 kg of coconut shell is stage added on the left and right sides of the tool and then the shells are burned in that space, but the shells are added in stages, two shells in the early stages, then added gradually until the end of ten shells. The purpose of doing the steps in the insertion of the coconut shell is to obtain a constant temperature (about 40 ℃-70 ℃) and relative humidity (<50%) in the drying chamber (Ajala, 2020; Warji and Tamrin, 2021).



A. Internet of Things network system, B. laptop or android phone, C. ventilator, D. biomass fire, E. dryer cabinets, and F. mini thermocouple.

Figure 1 Biomass-based post-harvest drying technology from coconut shell waste with the IoT system

2.1 Sample preparation

2.2 Workflow of data retrievals

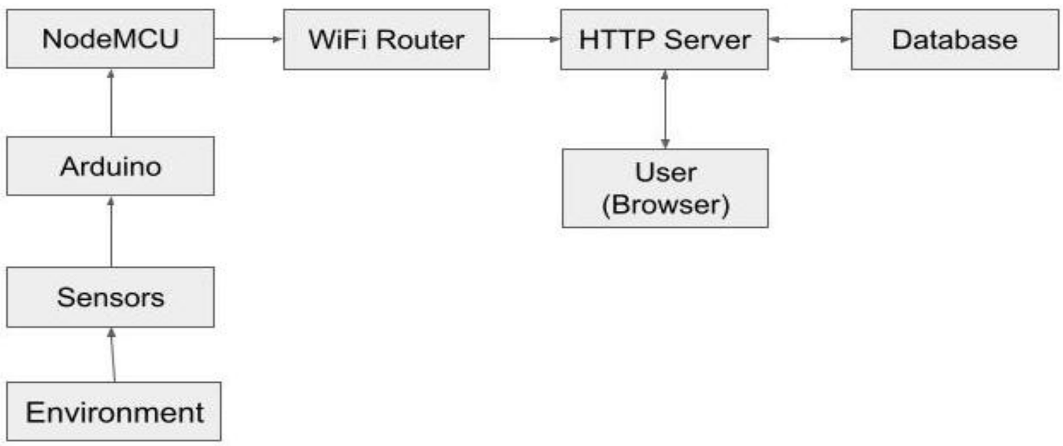


Figure 2 End to end data pipeline for the internet of things

The initial stage is to design a biomass energy dryer from coconut shell waste using the IoT system after the tool is ready to use, then enter the cassava sample that has been sliced earlier into the tool. Figure 2 is illustrated schematic process of remote monitoring of the dryer. The system for recording data on temperature and humidity as well as the water content of materials can be seen through the IoT system on an android cellphone. The programming to run the IoT system is given in Appendix.

2.3 Instrumentation

We installed a couple of moisture sensors (YL-69) on the left and right sides of each shelf for measuring the sample moisture, so totally there are 6 moisture sensors inside the dryer. A mini thermocouple is also installed in the dyer for measuring the temperature. The air temperature on the outer surface of the combustion drum is measured by a digital thermocouple. While the temperature in the drying chamber is measured through a sensor. The air humidity in the drying room is measured using a sensor system, then the data can be viewed on an Android phone with an IoT system.

Cassava raw materials that have been shaped as desired will then be dried using a dryer powered by coconut shell biomass waste energy using the IoT system. The cassava raw material is dried for two hours with several reiterations while the data can be directly recorded and can be observed on an Android cellphone.

3 Results and discussion

This research has demonstrated the use of post-harvest drying technology based on coconut shell biomass waste energy. The object being tested in this study is cassava crackers with a total mass of 10 kg, natural drying takes three days with sunny weather conditions, but if it rains, the conventional drying process outside will stop.

The heat energy from the combustion chamber will undergo a conduction process on the outer side of the combustion chamber, where the outer side of the combustion chamber is in the drying chamber, then from the outer side surface of the combustion chamber wall made of the drum, it will then undergo a radiation process to the drying chamber. The air in the drying chamber will be hot and then undergo a convection process in the drying chamber so that the air temperature in the drying chamber will increase and be higher than the outside air temperature. The temperature inside the drying chamber can reach more than 100 ℃. Another drying temperature of 40 ℃ to 70 ℃ for drying cassava chips has been conducted by an electric dryer (Warji and Tamrin, 2021; Sandra et al., 2021). This high temperature will reduce the water content of the cassava material so that it becomes dry. Through this post-harvest technology tool with the IoT system, the drying time is about two hours. While the coconut shell mass used is 250 gr each on the left and right, or 0.5 kg in total.

3.1 Sensor reading

The moisture sensor read a digital value in the range of 0-1023, as 10-bit Arduino sensor-based (Ajala et al., 2020). The moisture sensors working properly and the results of the reading value is depicted in Figure 3. These data will be calibrated and normalized for obtaining analog data. Of course, the accuracy of the sensors, especially YL-69, is quietly low, but the sensor is still capable for lab-scale and the cheapest among the existing moisture sensor system (Onashoga et al., 2021; Adla et al., 2020).

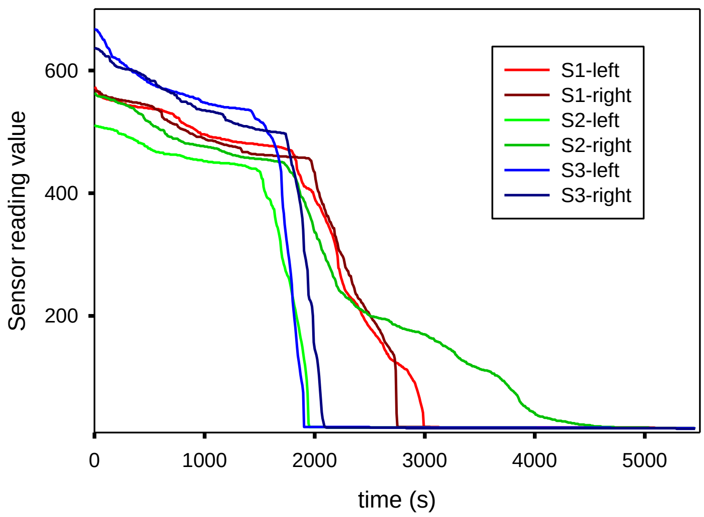


Figure 3 The reading data from the moisture sensors YL-96, two sensors for each shelf

3.2 Calibrated data

Some previous work on measuring moisture has been reported by researchers. There is an inverse relationship between digital data value (M_{ADC}) and the real value (Rose et al., 2019; Darmawan et al., 2020; Rose et al., 2021). The calibration of moisture value (M) has been set up and normalized in range of 0-100 % with the following equation.

$$M = -0.0997 M_{ADC} + 101.7 \quad (1)$$

Figure 4 shows all the measured parameters of the dryer, namely average moisture for each shelf, humidity, and temperature. The observation time lasted for two hours and was recorded for intervals of 8 seconds. The moisture contents are significantly dropped after 1500 s when the temperature rose to the highest. The steady moisture content is achieved below 10% after 3000 s. A similar result is also reported by Taiwo et al. (2014) work. Meanwhile, the humidity is stagnantly around 12% after 2000s drying time.

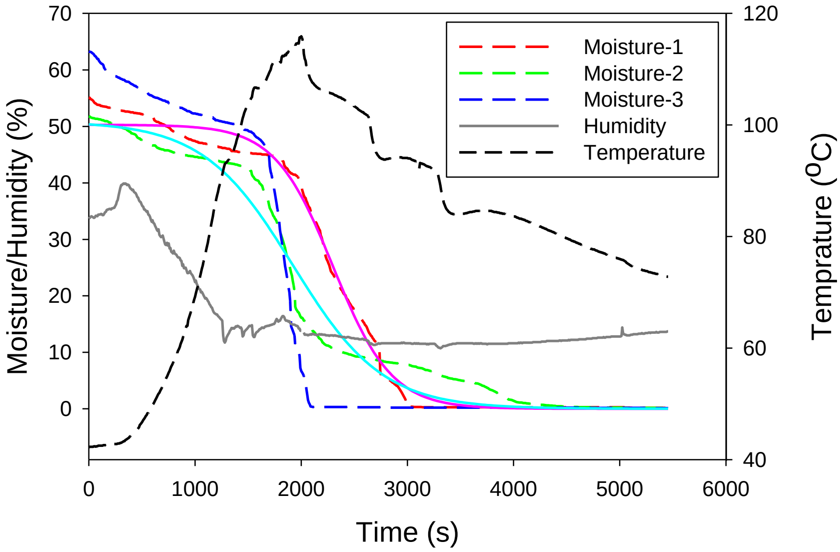


Figure 4 Plot of average moisture for each shelf, humidity and temperature of the proposed dryer

To maintain the temperature, the coconut shell as the biomass fuel is added about 2 kg to the firing drum when the flame is exhausted. Totally, 0.5 kg coconut shells were used during the drying process. After two hours, the moisture content of all the samples is below 10%, so the drying process is ended and the chips are put out to cool at room temperature.

3.3 Moisture loss rate prediction

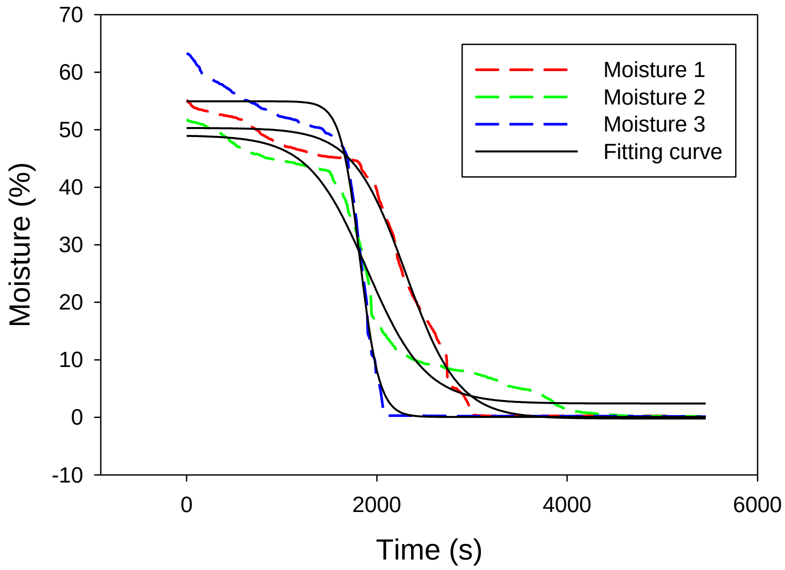


Figure 5 Fitting plot analysis of the moisture data

The moisture will be decreased as the temperature and drying time are increased. The moisture content loss-rate (MLR) can be predicted by fitting curve analysis. In our work, the fitting curve is given in Figure 5 and the parameters are provided in Table 1. All the fitting curves are followed sigmoidal equation for the moisture *M(t)*.

$$M(t) = M_0 + \frac{a}{1 + exp(\frac{t_0 - t_1}{b})} \tag{2}$$

where a, b (s) and t0 (s) are regression coefficients, and M0 is intercept. The MLR can be calculated by differentiating $M_{(t)}$ by the time.

$$MLR(t) = \frac{a(t_0 - t)exp(\frac{t_0 - t}{b})}{b^2(1+exp(\frac{t_0 - t}{b}))^2} \quad (3)$$

Table 1 Parameters of fitting curve analysis

	a	b	to	M_0	R^2
Shelve-1	50.5305	-278.219	2303.031	-0.2091	0.9947
Shelve-2	46.6381	-308.367	1895.816	2.4072	0.9836
Shelve-3	54.8862	-101.461	1821.726	0.0603	0.9935

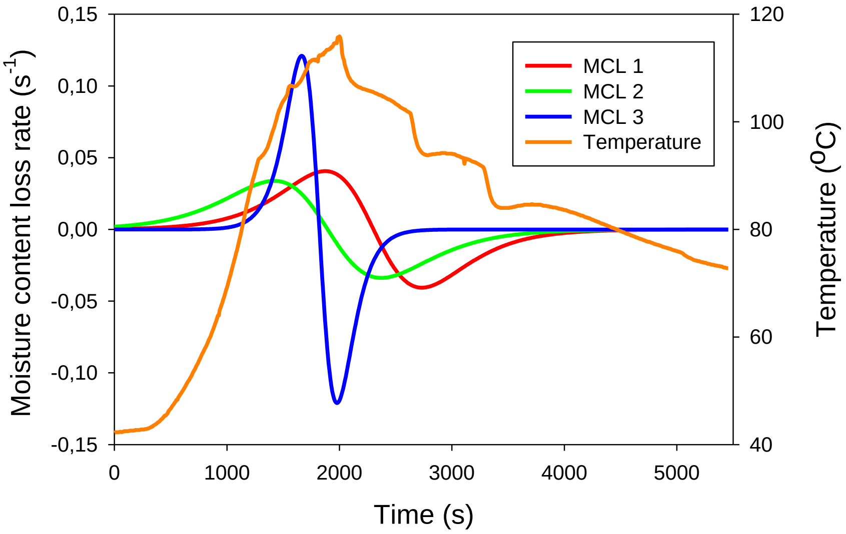


Figure 6 Prediction of the rate of moisture content loss of cassava chip drying in the biomass dryer

Figure 6 is depicted the MCL and temperature inside the dryer room. The peak MCL rate occurs when the temperature has risen to the highest point of 115.9 C. The chips in the below stack have the highest MCL rate up to 0.12% s^{-1} because its position is close to the firing drum, so the stack receives more heat.

4 Conclusion

We have successfully constructed and operated a biomass dryer with IoT system for remote monitoring. The dryer can load up to 10 kg fresh cassava chips and drying tie for two hours. The moisture contents are significantly dropped after 1500 s when the temperature rose to the highest. The peak MCL rate occurs when the temperature has risen to the highest point of 115.9 C. The chips in the below stack have the highest MCL rate up to 0.12%/s because its position is close to the firing drum. By using this dryer, it is very efficient to dry cassava crackers in just two hours.

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Appendix. The programing codes to command the IoT system

```
#include <DHT.h>
#include <ArduinoJson.h>
//Initialisation of DHT11 Sensor
#define DHTPIN 7
DHT dht(DHTPIN, DHT22);
float temp;
float hum;
int powerPin = 6;
void setup() {
 Serial.begin(4800);
 dht.begin();
 delay(1000);
 Serial.println("Program started");
}
void loop() {
 StaticJsonDocument<1000> doc;
 //Obtain Temp and Hum data
 dht11_func();
 //Assign collected data to JSON Object
 doc["humidity"] = hum;
 doc["temperature"] = temp;
 doc["hum1"] = getMoisture(0);
 doc["hum2"] = getMoisture(1);
 doc["hum3"] = getMoisture(2);
 doc["hum4"] = getMoisture(3);
 doc["hum5"] = getMoisture(4);
 doc["hum6"] = getMoisture(5);
 //Send data to NodeMCU
 serializeJson(doc, Serial);
 delay(500);
}
void dht11_func() {
 hum = dht.readHumidity();
 temp = dht.readTemperature();
 Serial.print("Humidity: ");
 Serial.println(hum);
 Serial.print("Temperature: ");
 Serial.println(temp);
```

```
}
int getMoisture(int analogPin) {
 int nilaiSensor = analogRead(analogPin);
 return 1023 - nilaiSensor;
}
```

NodeMCU:

```
#include <SoftwareSerial.h>
#include <ArduinoJson.h>
#include <ESP8266HTTPClient.h>
#include <ESP8266WiFi.h>
const char *ssid = "";
const char *pass = "";
unsigned long previousMillis = 0; // Timer to run Arduino code every 5 seconds
unsigned long currentMillis;
const unsigned long period = 1000;
String serverAddress = "http://lab.vick.xyz/api/sensor";
WiFiClient wifi;
void setup() {
 Serial.begin(4800);
 WiFi.begin(ssid, pass);
 while (!Serial) continue;
}
void loop() {
 //Get current time
 currentMillis = millis();
 if ((currentMillis - previousMillis >= period)) {
 StaticJsonDocument<1000> doc;
 DeserializationError error = deserializeJson(doc, Serial);
  float hum = doc["humidity"];
  float temp = doc["temperature"];
  if(hum != 0 andand temp != 0){
   HTTPClient http;
   http.begin(serverAddress);
   http.addHeader("Content-Type", "application/json");
   Serial.println("JSON Object Recieved");
   Serial.print("Recieved Humidity: ");
   Serial.println(hum);
   Serial.print("Recieved Temperature: ");
   Serial.println(temp);
```

```
  char JSONmessageBuffer[500];
  //doc.printTo(JSONmessageBuffer, sizeof(JSONmessageBuffer));
  serializeJson(doc, JSONmessageBuffer);
  int httpCode = http.POST(JSONmessageBuffer);
  String payload = http.getString();
  Serial.println(payload);
  Serial.println(httpCode);
  Serial.println("----------------------------------------");
 }
 previousMillis = previousMillis + period;
 }
}
```

HTTP Server

```
import os
import sys
from datetime import timedelta
from flask import (
 Flask,
 render_template,
 request,
 redirect,
 flash,
 send_from_directory,
 jsonify,
)
app = Flask(
 __name__,
 template_folder="../templates/",
 static_folder="../static",
 static_url_path="/static",
)
app.config["SECRET_KEY"] = "Y29zbWlxbwo="
app.config["UPLOAD_FOLDER"] = os.getcwd() + "/static/"
sys.path.append(os.getcwd())
from src.data_utils import get_sensor_raw, get_latest_data, post_raw

# ----------------- MAIN ROUTERS --------
@app.route("/")
def main_view():
```

```
 """main app"""
 return render_template("index.html", page="tabular")
@app.route("/visualizer")
def visualizer_view():
 """visualizer view"""
 return render_template("visualizer.html", page="visualizer")
@app.route("/download")
def download_data():
 download_fn = get_sensor_raw("room2")
 download_fn = download_fn.split("/")[-1]
 return send_from_directory(
  app.config["UPLOAD_FOLDER"], download_fn, as_attachment=True
 )
# ----------------- API -----------------
@app.route("/api/sensor", methods=["POST"])
def post_raw_sensor():
 """receive latest sensor update"""
 raw_sensor = request.json
 ok = post_raw(raw_sensor)
 resp = "success" if ok else "failed to update sensor data"
 return jsonify({"msg": resp})
@app.route("/api/latest", methods=["GET"])
def get_raw_json():
 """get last row data from db"""
 raw_data = get_latest_data()
 raw_data = {"raw": raw_data}
 return jsonify(raw_data)
```

Utility Script

```
import sys
import os
import pandas as pd
import fire
from datetime import datetime
from influxdb import InfluxDBClient
sys.path.append(os.getcwd())
from config import DB_HOST, DB_USER, DB_PASSWORD, DB_PORT, DB_NAME
def get_influx_client():
 try:
  return InfluxDBClient(DB_HOST, DB_PORT, DB_USER, DB_PASSWORD, DB_NAME)
```

```
  except Exception as err:
    print(err)
    return None
def get_sensor_raw(measurement):
  client = get_influx_client()
  result = list(client.query(f"select * from {measurement}").get_points())
  if not result:
    return None
  df = pd.DataFrame(result)
  now = datetime.now()
  now_ts = int(now.timestamp())
  output_fn = datetime.now().strftime("%Y-%m-%d")
  output_fn = os.getcwd() + f"/static/{output_fn}-{now_ts}.csv"
  df.to_csv(output_fn, index=False)
  return output_fn
def get_latest_data():
  client = get_influx_client()
  result = list(client.query("select * from room2 order by time desc limit 1"))
  if not result:
    return None
  return result[0]
def post_raw(raw_data):
  client = get_influx_client()
  raw_data = {k:float(v) for k, v in raw_data.items()}
  raw_data = [
    {
      "measurement": "room2",
      "tags": {"device": "esp82661", "SSID": "123456"},
      "fields": raw_data,
    }
  ]
  resp = client.write_points(raw_data)
  return resp
def test_post_raw():
  raw_data = {
    "temp": 0.64,
    "humidity": 0.64,
    "mois_1": 0.64,
    "mois_2": 0.64,
```

```
    "mois_3": 0.64,
    "mois_4": 0.64,
    "mois_5": 0.64,
    "mois_6": 0.64,
  }
  resp = post_raw(raw_data)
  print(resp)
if __name__ == "__main__":
  fire.Fire()
```