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# VARIATION MODELS OF SOME AIR QUALITY PARAMETERS IN AN EXPERIMENTAL GLASS MODULE WITH FRUIT

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## ABSTRACT

*The study evaluated the variation of some air quality parameters in an experimental module, laboratory conditions, within the University of Life Sciences "King Mihai I" from Timisoara. The experimental module was represented by a cylindrical glass vessel with a volume of 5969 $cm^3$. Six apples, the 'Jonathan' variety, and the Temtop LKC-1000S+ $2^{nd}$ device were positioned in the experimental module. Isolation of the air in the experimental module from the laboratory air was ensured. Air quality parameters (PM2.5, PM10, Particle, AQI, HCHO, TVOC, Temperature, and Humidity) were monitored at five-minute intervals, over a time interval (Time) of 105 minutes. Variable levels of correlation between air quality parameters were identified. Exponential models described the variation of air quality parameters in relation to time, in statistical safety conditions.*

## INTRODUCTION

Air pollution is a significant reality for environmental sustainability, the quality of food resources, public health (Abdelmalek et al., 2025). Air quality indices are important for expressing the level of air quality or the state of contamination with various substances (Horn and Dasgupta, 2024; Andenna and Gagliardi, 2025). Air quality can be assessed based on specific indices for certain substances (e.g. PM2.5, PM10, particle, HCHO, $NO_2$, $SO_2$, etc.), or based on a synthetic index (e.g. AQI) that homogenizes different metric indices (Horn and Dasgupta, 2024). As a result of the importance of knowing air quality, various techniques, methods and models for monitoring and forecasting specific indices have been promoted (Abdelmalek et al., 2025; Ma et al., 2025).

Air quality and its potential impact on agricultural production and food security has been the subject of recent studies (Manono et al., 2025). Agriculture, through agricultural technologies, contributes significantly to the deterioration of air quality, with an impact on the environment, human health and dietary changes (Huang et al., 2025; Luo et al., 2025).

Horticultural products (fruits, vegetables) are stored in spaces with controlled conditions (e.g. temperature, humidity, etc.) due to their perishable nature (Lal Basediya et al., 2013; Ho et al., 2021). During the storage of fruits and vegetables, a series of chemical, physiological, and biochemical transformations

take place, in relation to certain specific pre-treatments, storage conditions, and storage time (Lal Basediya et al., 2013; Ahmed et al., 2023; Jia et al., 2025; Suran et al., 2025). Changes in the quality of fruits and vegetables under home storage conditions, associated with certain specific practices, were evaluated (Ballan et al., 2025; Cuozzo et al., 2025). In fruit storage and storage space, changes in air quality indices occur as a result of physiological, chemical and biochemical processes in the products, with $O_2$ consumption and $CO_2$ release, ethylene gas through respiration, moisture loss, etc. (Prange et al., 2025).

The present study evaluated air quality indices, their interdependence and variation over time, under laboratory conditions, experimentally with apples, Golden variety, with controlled air volume, isolated from ambient air.

## MATERIAL AND METHODS

The study was conducted under laboratory conditions, within the University of Life Sciences "King Mihai I" from Timisoara, in 2026. In relation to the purpose of the study, an experimental module represented by a cylindrical glass container, with a volume of 5969 $cm^3$, was used. Six apples, the 'Jonathan' variety, and the Temtop LKC-1000S+ 2$^{nd}$ generation device, for measuring air quality parameters, were positioned in the experimental module. The isolation of the air in the experimental module from the air in the laboratory was ensured. The variation of some air quality parameters was monitored over 105 minutes, with the values recorded at five-minute intervals. This resulted in series of 22 values for each parameter.



Figure 1. Experimental module – schematic diagram; glass container, fruit, measuring device

Values were recorded for the following parameters: PM2.5 (µg/$m^3$), PM10 (µg/$m^3$), particulate matter (PM; a complex mixture of solid particles and liquid droplets floating in the air), Air Quality Index (AQI; AQI 0 – 50 (Good): Clean air, no health risks); formaldehyde (HCHO; recommended < 0.035–0.05 mg/$m^3$), Total Volatile Organic Compounds (TVOC, mg/$m^3$); temperature (T, °C), humidity (RH, %). The data series were analyzed using appropriate mathematical and statistical tools to assess the reliability of the data, the presence of variance, the interdependence between the determined parameters, and the distribution of values with respect to time. The PAST software v.4.14 (Hammer et al., 2001) and the JASP software v.0.16.2. (2022) were used for data analysis and generation of graphical representations.

## RESULTS AND DISCUSSIONS

The data series (N = 22) were statistically analyzed, and the values of the statistical parameters are presented in Table 1. PM2.5 values ranged from PM2.5 = 0.10±0.33 μg/m³ to PM2.5 = 5.40±0.33 μ g/m³. The recorded values were within the permitted limits (0 – 50 μg/m³, or equivalent index: good, satisfactory air). The PM10 parameter presented values between PM10 = 0.10±0.55 μg/m³ to PM10 = 9.00±0.55 μg/m³. The recorded values were below the recommended limit (daily average: 50 μg/m³).

Table 1

Air quality parameter values under study conditions

| Statistical parameters | PM2.5 | PM10 | Part | AQI | HCHO | TVOC | T | RH |
|---|---|---|---|---|---|---|---|---|
| Valid | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Missing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Median | 0.40 | 0.70 | 107.00 | 2.00 | 0.07 | 0.32 | 22.60 | 76.20 |
| Mean | 1.15 | 1.90 | 214.77 | 4.86 | 0.06 | 0.30 | 22.86 | 75.56 |
| Std. Error of Mean | 0.33 | 0.55 | 54.62 | 1.31 | 0.00 | 0.01 | 0.12 | 0.51 |
| Std. Deviation | 1.56 | 2.58 | 256.20 | 6.13 | 0.01 | 0.04 | 0.56 | 2.41 |
| Minimum | 0.10 | 0.10 | 10.00 | 1.00 | 0.05 | 0.20 | 22.40 | 68.30 |
| Maximum | 5.40 | 9.00 | 882.00 | 22.00 | 0.07 | 0.34 | 24.30 | 77.70 |
| 25th percentile | 0.20 | 0.30 | 51.00 | 1.00 | 0.06 | 0.28 | 22.50 | 74.98 |
| 50th percentile | 0.40 | 0.70 | 107.00 | 2.00 | 0.07 | 0.32 | 22.60 | 76.20 |
| 75th percentile | 1.43 | 2.38 | 263.00 | 5.25 | 0.07 | 0.33 | 23.00 | 77.60 |

The particle parameter (Part) presented values ranging from Part = 10.00±54.62 μg/m³ to Part = 882.00±54.62 μg/m³. The AQI parameter presented values ranging from AQI = 1.00±1.31 to 22.00±1.31, and fell within the range (0, 50), which indicated good quality air. The HCHO parameter showed values ranging from HCHO = 0.05±0.00 mg/m³, to HCHO = 0.07±0.00 mg/m³. The values indicated good air quality. The TVOC parameter showed values ranging from TVOC = 0.20±0.01 mg/m³, to TVOC = 0.34±0.01 mg/m³. The recorded values indicated good air quality. The T parameter recorded values ranging from T = 22.40±0.12 °C to T = 24.30±0.12 °C. The RH parameter presented values ranging from RH = 68.30±0.51 % to RH = 77.70±0.51 %. The ANOVA test (Alpha = 0.05), Table 2, confirmed the statistical reliability of the experimental data, and the presence of variance in the data set.

Table 2

ANOVA Test results

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 868345.2 | 7 | 124049.3 | 15.1072 | 3.07E-15 | 2.0644 |
| Within Groups | 1379496 | 168 | 8211.286 | | | |
| Total | 2247841 | 175 | | | | |

The data series showed a normal distribution, with values ranging from r = 0.816 (AQI parameter) to r = 0.934 (TVOC parameter). Outlier test (Grubbs, Dixon Q) was applied to identify possible outliers in the data series, Table 3. For most parameters and values in the data series, no outliers were recorded (p>0.05). In the case of the AQI parameter, and in the case of the RH parameter, one outlier value was recorded (p<0.05).

Table 3

Outliers Test results

| Test and parameters | PM2.5 | PM10 | Part | AQI | HCHO | TVOC | T | RH |
|---|---|---|---|---|---|---|---|---|
| Grubbs test | | | | | | | | |
| G | 2.717 | 2.757 | 2.604 | 2.796 | 1.876 | 2.679 | 2.575 | 3.010 |
| p | 0.060 | 0.050 | 0.099 | p<0.05 | 1.000 | 0.072 | 0.112 | p<0.05 |
| Dixon Q test | | | | | | | | |
| Q (r22) | 0.321 | 0.307 | 0.285 | 0.333 | 0.000 | 0.357 | 0.263 | 0.441 |
| p | 0.322 | 0.365 | 0.436 | 0.288 | 1.000 | 0.225 | 0.508 | 0.075 |

The correlation analysis indicated different levels of correlation of air quality parameters in relation to the time factor (Time, min), as well as between air quality parameters, under statistical safety conditions (p<0.001, ***), Figure 2.

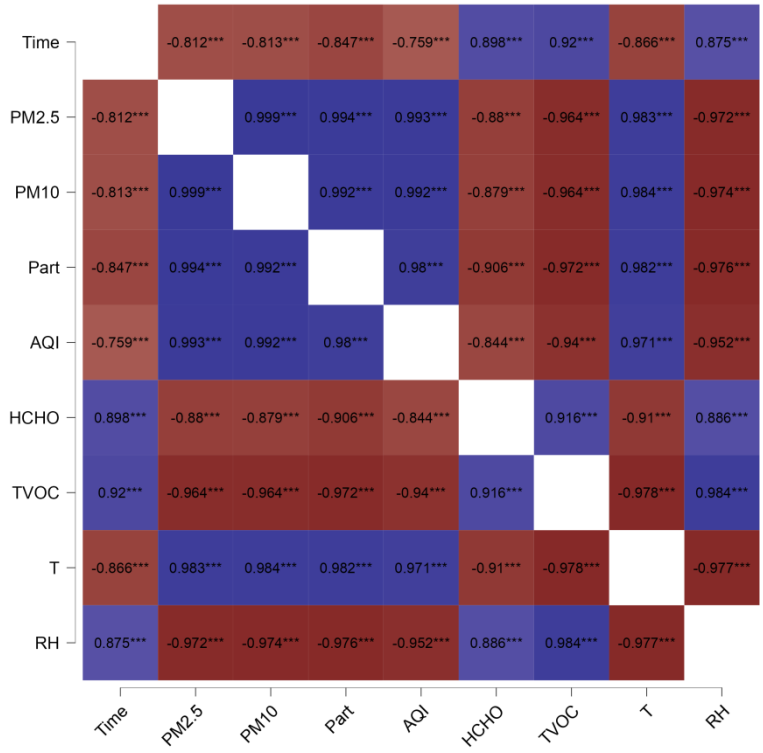



Figure 2. Correlation matrix

Positive correlation with the time factor (Time), of very strong and strong intensity, was shown by the TVOC parameter (r = 0.92, ***), the HCHO parameter (r = 0.898, ***) and the RH parameter (0.875, ***). The other parameters showed a negative correlation with the time factor (Time), of strong and moderate intensity (p<0.001). The temperature parameter (T, °C) showed a very strong, positive correlation with the PM2.5, PM10, Part, AQI parameters and a negative correlation with the HCHO and TVOC parameters. The humidity parameter (RH) showed a similar correlation in intensity, but positive with HCHO and TVOC parameters, and negative with PM2.5, PM10, Part, AQI. The PM2.5, PM10, Part and AQI parameters showed a positive correlation, of very strong intensity, and in relation to HCHO and TVOC parameters, the respective parameters showed a negative correlation, of very strong and strong intensity.

The variation of temperature (T) in relation to humidity (RH) in the experimental module was described by a 3rd degree polynomial model, Equation (1), under conditions of $R^2 = 0.985$, F = 401.4, p<0.001.

$$T = 0.005231x^3 - 1.156x^2 + 84.89x - 2046 \quad (1)$$

where: T – temperature (°C), $x$ – relative humidity (RH, %)

In relation to the time factor, decreasing variation was recorded in the case of the PM2.5, PM10, Part, AQI, and T parameters, respectively an increasing variation in the case of the HCHO, TVOC, and RH parameters. The Mann-Kendall test confirmed the significant trend of variation in the data series, Table 4.

Table 4

Mann-Kendall trend Test results

| Statistical parameters | PM2.5 | PM10 | Part | AQI | HCHO | TVOC | T | RH |
|---|---|---|---|---|---|---|---|---|
| S | -205 | -199 | -213 | -144 | 145 | 211 | -191 | 212 |
| Z | -5.806 | -5.604 | -5.983 | -4.161 | 4.501 | 5.992 | -5.445 | 5.997 |
| p | p<0.001 | | | | | | | |
| Data series trend | dt | dt | dt | dt | it | it | dt | it |

Note: dt – decreasing trend ; it – increasing trend

The variation of the PM2.5 parameter in relation to time (Time, min) was described by the exponential model, equation (2), under conditions of $R^2 = 0.986$, p<0.001, with the graphical distribution in Figure 4.

$$PM2.5 = 5.6535 \cdot e^{-0.053387x} + 0.073423 \quad (2)$$

where: PM2.5 – air quality parameter; $x$ – measurement time

The graph of equation (2) represents an exponential decay curve, characterized by a continuous decrease and a horizontal asymptote at the value Y = 0.073423. The graphical expression represents a smooth decreasing exponential curve, which starts in the second quadrant, crosses the y-axis at height 5.727, and

folds asymptotically above the x-axis along the line y = 0.073423.

The variation of the PM10 parameter in relation to time (Time, min) was described by the exponential model, equation (3), under conditions of $R^2$ = 0.987, p<0.001, with a distribution similar to the PM2.5 parameter.

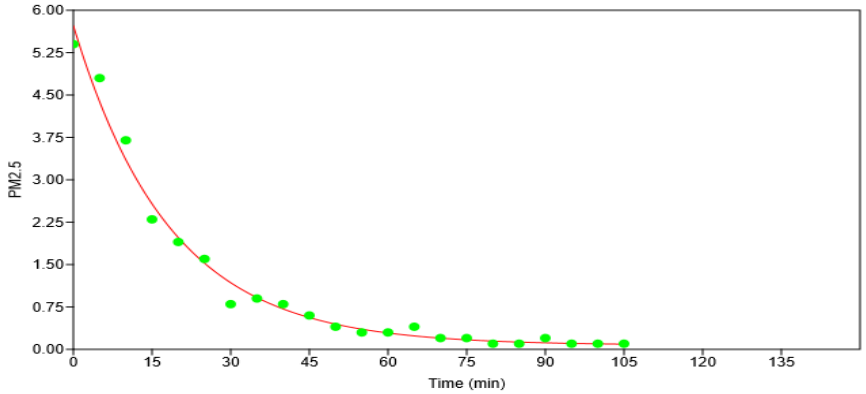



Figure 3. Graphical expression of equation (2)

$$PM10 = 9.3144 \cdot e^{-0.05423x} + 0.11738 \quad (3)$$

where: PM10 – air quality parameter; $x$ – measurement time

The expression of equation (3) represents an exponential decrease, which starts from the value y = 9.43178, for x = 0, and asymptotically decreases towards the limit value 0.11738, as x tends to infinity.

The variation of the AQI parameter in relation to time (Time, min) was described by the exponential model, equation (4), under conditions of $R^2$ = 0.977, p<0.001, with the graphical distribution in Figure 4.

$$AQI = 22.476 \cdot e^{-0.06196x} + 1.0335 \quad (4)$$

where: AQI – air quality parameter; $x$ – measurement time

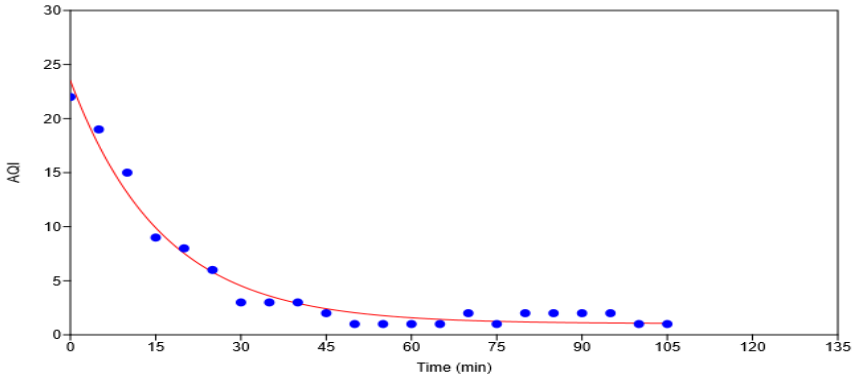



Figure 4. Graphical expression of equation (4)

The graphical expression of equation (4) represents an exponential decay curve (attenuation), which starts from the value y = 23.5095 (for x = 0) and decreases asymptotically, towards a positive limit value y = 1.0335 (for $x \to \infty$).

The variation of the TVOC parameter in relation to time (Time, min) was described by equation (5), under conditions of $R^2 = 0.982$, $p<0.001$, Figure 5.

$$\mathrm{TVOC} = 0.34076 \cdot \left(1 - 0.38785 \cdot e^{-0.032034 \cdot x}\right) \quad (5)$$

where: TVOC – air quality parameter; $x$ – measurement time

The equation (5) graphical expression is an exponential capping curve (similar to the von Bertalanffy model) that starts from the point (0, 0.2086), rises smoothly and tends asymptotically towards the maximum limit ($Y_{max} = 0.34076$).

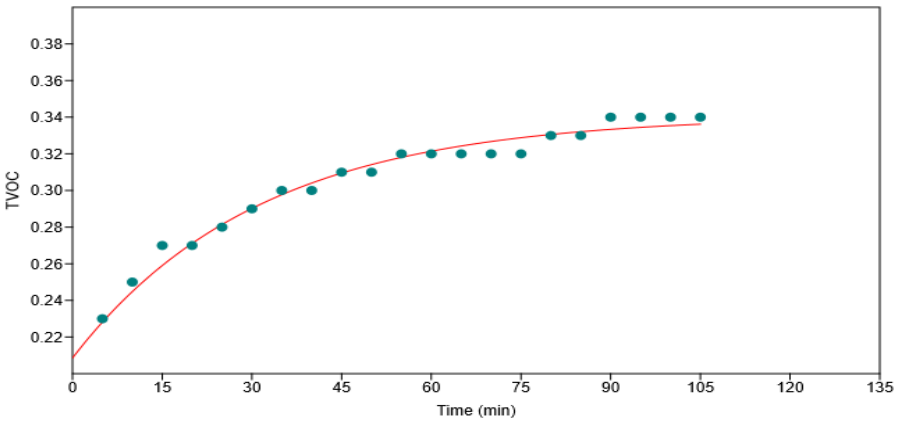



Figure 5. Graphical expression of equation (5)

## CONCLUSIONS

Air quality parameters, under the conditions of the conceptual experimental module, varied differentially, in close interdependence and causal relationships with the time factor. Variable correlation as action and intensity ($p<0.001$) was recorded between determined quality parameters. Negative interdependence was found between temperature and air humidity in the experimental module. Parameters PM2.5, PM10, Part, AQI, and T varied decreasingly with time (Time, min), according to exponential models, with asymptotic decrease, and parameters HCHO, TVOC, and RH varied increasingly with time, according to exponential models with asymptotic increase, under conditions of statistical safety. The obtained results recommend the development of research to quantify physiological and quality phenomena in different categories of fruits and vegetables under temporary storage conditions.

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