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Effects of Different Power Levels Used in Microwave Drying Method on Color Changes of Oyster Mushroom (*Pleurotus Ostreatus)*

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ABSTRACT: Color of dried edible material is one of the most essential considerations for consumers when making product purchases. The similarity between the color of the dried product and the color of the fresh product increases their marketability. The primary objective of drying operations is to dry products with minimal energy consumption, to prevent the growth of microorganisms, preserve their flavor and nutritional value, to make the moisture content suitable for storage, and to ensure that the color change after drying closely resembles that of the fresh product. This study seeks to dry Oyster mushrooms (*Pleurotus spp.*) at different drying power levels (90 W, 180 W, 360 W, and 600 W) using the microwave drying method of thin slices and to determine the color changes of the dried mushrooms. As a result of the trials carried out in the laboratory, it was discovered that the increase in drying power caused the samples to dry faster. At the end of the drying period, the colors of the mushrooms became darker than the initial levels. The highest change in brightness was recorded during the drying process at a power of 90 W. In the investigation, it was determined that the drying time was longer and the color change of the dried product was greater when the power was 90 W. Based on this, it can be stated that the color changes of the product will exhibit less deformation if the desired humidity level is obtained quickly during the drying process using the thin slice microwave drying method. However, this should just be viewed as a suggestion for minimizing color change. Numerous criteria, including color change, drying duration, nutrient content, and shelf life, should be assessed concurrently while determining the drying process.

Keywords: Drying, mushroom, microwave, color change, food processing

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INTRODUCTION

Drying is one of the most effective techniques for preserving food without compromising its nutritional content. This technique aims to inhibit the growth of microbes by removing the free water from the product to be dried, hence extending its shelf life. However, it is not possible to extend the shelf life without losing nutritional value if the moisture content is not lowered to the necessary level within a particular time frame during the drying process. For the procedure to be effective, it is crucial that the moisture content of the product is reduced to 10 to 15% during the drying process (Demiray, 2009) and that the color change is kept to a minimum (Mousa and Farid, 2002).

Mushrooms are high-nutritional-value foods that are used for nutritional purposes. Forty to fifty percent of the world's edible mushroom production is consumed fresh. Due to its high moisture and enzyme content, harvested mushrooms can only be stored for 1 to 7 days, during which time their quality rapidly degrades. Methods such as canning, freezing, and drying are used to improve the shelf life of mushrooms (Erbay and Kucukoner, 2008). Drying is a less expensive alternative to other procedures. In addition, the product can be preserved in airtight packaging for more than a year using this procedure (Bano et al., 1992; Rama and John, 2000).

Oyster mushrooms are nutritionally dense. In addition, its cholesterol-lowering, anti-diabetic, and antihypertensive characteristics make it a popular health product (Bobek et al., 1991; Schneider et al., 2011; Afrin et al., 2016). When examining the distribution of global farmed mushroom production by species, Agaricus Bisporus and Oyster species come out on top with 37.8% and 24.2%, respectively. In Turkey, surplus mushrooms are exported as chilled, frozen, and dried products to overseas markets.

Utilizing solar energy, hot air, or freeze-drying, mushrooms are dried. Temperatures between 55°C and 65°C are typically used in hot air-drying processes. (Eksi, 1980) Mushrooms must be dried to a relative humidity level of 10 to 12% before they may be stored properly and without degrading. Celen (2004) indicated that mushrooms should be dried to a moisture level of 5%, and the drying temperature should not exceed 65 °C. In addition, he reported that in the last stages of drying, more energy is required to remove the remaining moisture from the dried product; therefore, identifying the safe moisture content is crucial for energy conservation.

Thin slice microwave drying method; is a technology that can be used to reduce drying time, improve the quality of dried items, and save energy (Kumar et al., 2016). In this process, a magnetic field is generated using a magnetron generator, and heat is generated by the vibration of water molecules. All of the material to be dried is heated uniformly in this manner. Therefore, the drying process with microwave energy is more effective, uniform, and rapid (Konak et al., 2009). Additionally, since volumetric heating (Wray and Ramaswamy, 2015) is applied to the material being dried, the drying rate is accelerated (Nair et al., 2015).

Tugrul et al. (2005) evaluated the drying behavior of mushrooms cut into cubes with 0.5, 1, and 1.5 cm thickness. In the study in which an infrared drier was utilized, values of 50°C, 60°C, and 80°C were used as drying air temperatures. As a result of the investigation, it was established that the drying times decreased dependent on the increase in the temperature speed. In addition, the increase in temperature and slice thickness enhanced the diffusion coefficient.

Oyster mushrooms were dried using hot air in another study. Temperature (50°C, 60°C, 70°C) and drying time (240, 300, and 360 minutes) increase the dry matter content, a*, and b* color values in the study. The color value of L* has decreased (Dogan et al., 2014).

The drying properties and color changes of Oyster mushrooms (*Pleurotus ostreatus*) dried using a thin slice microwave drying method were investigated in this study. Mushrooms were dried in a microwave oven at different power levels to assess moisture and color changes during the drying process.

MATERIALS AND METHODS

Oyster mushroom used as drying material was obtained from the mushroom production facility established within the Faculty of Agriculture at Igdir University. Drying was accomplished in a microwave oven with adjustable power levels. The sample weights before and after drying were determined using a precision balance with a sensitivity of 0.0001. The color changes of the samples before and after drying were measured using a spectrometer (Figure 1).

After washing and cleaning the mushrooms, they were chopped into cubes with an average diameter of 5 cm and boiled at 100 °C for three minutes. Until they were cooled and dehydrated, boiled mushrooms were stored in ziplock polyethylene bags at -18 °C (Yildiz et al., 2015). To lengthen the shelf life of mushrooms, it is recommended in the literature that their moisture content be lowered to 10 to 12% (Eksi, 1980). Before beginning the drying procedure, the moisture content of the samples was measured. To do this, a 100 g sample was wrapped in aluminum foil and dried at 105 °C for 24 hours, and the moisture content was estimated using Equation 1 (Akpinar and Bicer, 2002; Kahveci and Cihan, 2007).

$$m_y = \frac{m_s}{(m_s + m_k)} \tag{1}$$

In the equality;

m_y: moisture content (%),

m_s: wet mass of the product (g),

m_k: dry mass of the product (g)

In this study, thin slice microwave drying method was utilized. Following this purpose, roughly 200 g of mushroom samples were microwave-dried three times at different power levels to reduce the moisture content to 10-12%. Throughout the drying period, samples were weighed at regular intervals in accordance with their drying power, and the moisture changes were computed using Equation 2. (Bayhan, 2011).

$$mr = \frac{m - m_e}{m_0 - m_e} \tag{2}$$

In equality;

m_r: dimensionless humidity,

m: moisture content of the product at a given time (g water/g solid),

m_e: equilibrium moisture content,

m_0 represents the initial moisture content.

Because the amount of water in the air during drying conditions is generally small in comparison to other moisture amounts, it has been overlooked in many studies. The value of "me" was ignored in the study as a result of this approach.

During the drying of the mushrooms, fresh and dried samples were measured for color to investigate the impact of drying conditions on the color changes of biological material. According to the worldwide L*a*b* system, color measurement was performed (Soysal, 2000). The "L*" value used in the study represents the brightness and ranges from 0 to 100. Zero (0) indicates blackness and one hundred (100) indicates whiteness in the value of " L* ". In addition, the "a*" value is a measure of redness and greenness, and the "b*" value is a measure of blueness and yellowness, with values ranging from -90 to +90. Using Equations 3 and 4, the metric color tones (α) and metric chroma (C) values of the samples were determined using the "a*" and "b*" values during the drying time (Feng and Tang, 1998).

$$\alpha = arctan = \frac{b^*}{a^*} \quad (3)$$

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (4)$$

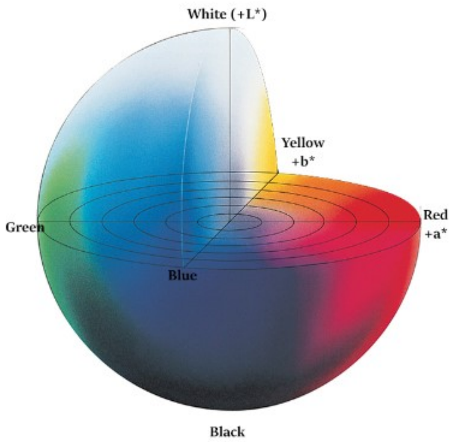

Figure 1. CIE L*, a*, b* color space

In calculating the color change; total color aberration (ΔE), chroma aberration (ΔC), color brightness aberration (ΔL), red chromatic aberration (Δa), yellow chromatic aberration (Δb) was evaluated with the use of the equations given in Equations 5–9 (Feng and Tang, 1998). The methodologies to be followed for the interpretation of these values are described in Table 1.

$$\Delta L = L_{fresh} - L^* \quad (5)$$

$$\Delta a = a_{fresh} - a^* \quad (6)$$

$$\Delta b = b_{fresh} - b^* \quad (7)$$

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (8)$$

$$C = C^*_{Sample} - C^*_{standard} \quad (9)$$

Table 1. Color change parameters

Parameter	Positive value	Negative value
ΔL	It means that the color brightness of the dried product is higher than the color brightness of the fresh product.	It means that the color brightness of the dried product decreases compared to the fresh product.
Δa	It means that the green color in the dried product is lower than the green color of the standard fresh product.	It means that the green color in the dried product increases compared to the fresh product.
Δb	It means that the yellow color in the dried product is higher than the yellow color of the fresh product.	It means that the yellow color of the dried product is reduced compared to the fresh product.
ΔE	Total chromatic aberration	Expresses the total deviation in color values
ΔC	Indicates that the saturation of the sample is more than the standard.	For example, it means that it is less saturated and grayer than the standard.

Statistical analysis

Experimental data were analyzed and presented as mean values and standard deviations of triplicate data. Results were subjected to analysis of variance (ANOVA), and post hoc comparison of the means was performed by the Duncan tests at $p < 0.05$ using SPSS 25 analytical software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

RESULTS AND DISCUSSION

Results of Color Changes in the Drying Process

The main purpose of drying studies is to prevent microorganism growth with minimal energy consumption, to preserve taste and nutritional values, to make the moisture content suitable for storage conditions, as well as to have color values close to the fresh product. It is reported that there may be many reactions such as pigment degradation (especially carotenoids and chlorophyll), browning reactions (such as Maillard condensation of hexoses and amino components) and oxidation of ascorbic acid (Barreiro et al., 1997, Lozano and Ibarz, 1997, Lee and Coates, 1999) which can affect the color factors of the dried products. Also, fruit colour, acidity, temperature and its duration affect the colour (Abers and Wrolstad, 1979, Skrede, 1985, Garcia-Viguera et al., 1999).

Difference in change in color parameters (in L*, a*, b* color space) between dried and fresh material represent lower quality. In the experiments on drying, it was stressed that the gloss values (L*) of the dried product should be high and that the difference (L) between the fresh and dried product should be small (Raj and Dash, 2020). In the study, the gloss values (L*) of oyster mushrooms were 26.09 (±0.05), 27.92 (±1.25), 33.82 (±0.785), and 36.68 (±4.175) at 90 W, 180 W, 360 W, and 600 W microwave power levels, respectively (Table 2). The variation of L*, a*, and b* values as a function of drying time and drying power is depicted in Figure 3. In general, the increase in drying time decreased the L* value and increased the a* and b* values. L* values for dried product increased compared to fresh product. This can be explained by exposure of samples during drying which causes enzymatic and non-enzymatic browning reactions (Argyropoulos et al., 2011). L* increase as power levels increase in drying process. In other words, power density (product temperature) and L* are inversely proportional. This is because time it takes to reach (Krokida et al., 1998) the desired humidity level is different at the lowest and highest power levels (Min et al., 2005). a* and b* increased in parallel with drying time. While a colour shift towards to positive a-direction indicates more redness, shift to positive b-direction indicates more yellowness.

The effects of applied drying powers on the brightness changes (ΔL) of the product are given in Table 2. When Table 2 is examined, it is seen that ΔL values are negative at all power levels. As an expected result, the drying process caused a decrease in the color brightness of the product. The smallest difference between the drying powers in terms of brightness change (ΔL) of fresh and dried products was obtained at 600 W drying power level with a value of -28.36. This value; drying power levels were followed by -32.31 to 360 W, -38.65 to 180 W, and -41.59 to 90 W (Table 2). In the research, there is an increase in ΔL value depending on the increase in drying power. One of the most important reasons for this is that the drying speed increases depending on the drying power and the desired humidity level is reached in a shorter time.

As a result of drying operations, Δa and Δb values were positive (Table 2). This is an indication that there are increases in red and yellow tones in the dried product compared to the fresh product. In the study, the highest difference in Δa value was obtained between 12.07 and 600 W drying power level, while the biggest difference in Δb value was found with 37.20 at 360 W drying power level.

Table 2. Color parameter values of samples dried at different power levels

Drying Power	Condition	L*	a*	b*	α	C	ΔL	Δa	Δb	ΔE	ΔC
90 W	I	67.68	5.20	13.05	1.19	14.04	0.00	0.00	0.00	0.00	0.00
	F	26.09	12.17	48.18	1.32	49.69	-41.59	6.98	35.13	54.89	36.64
180 W	I	66.57	6.02	13.61	1.15	14.89	0.00	0.00	0.00	0.00	0.00
	F	27.92	11.21	37.12	1.28	38.78	-38.65	5.19	23.51	45.54	25.17
360 W	I	66.12	6.33	15.47	1.18	16.71	0.00	0.00	0.00	0.00	0.00
	F	33.82	15.17	52.67	1.29	54.81	-32.31	8.84	37.20	50.06	39.34
600 W	I	65.03	4.52	12.61	1.23	13.40	0.00	0.00	0.00	0.00	0.00
	F	36.68	16.59	34.92	1.13	38.66	-28.36	12.07	22.31	38.04	26.05

L: brightness (0 blackness, 100 whiteness), a: (-90 green, +90 red), b: (-90 blue, +90 yellow), I: initial state, F: final state

The metric chroma value represents gloss and opacity. The greater the metric chroma value, the brighter the product's color, and the lower the value, the more matte the color. Figure 4 depicts the impact of drying at different power levels on the metric chroma and hue (α) values during the drying process.

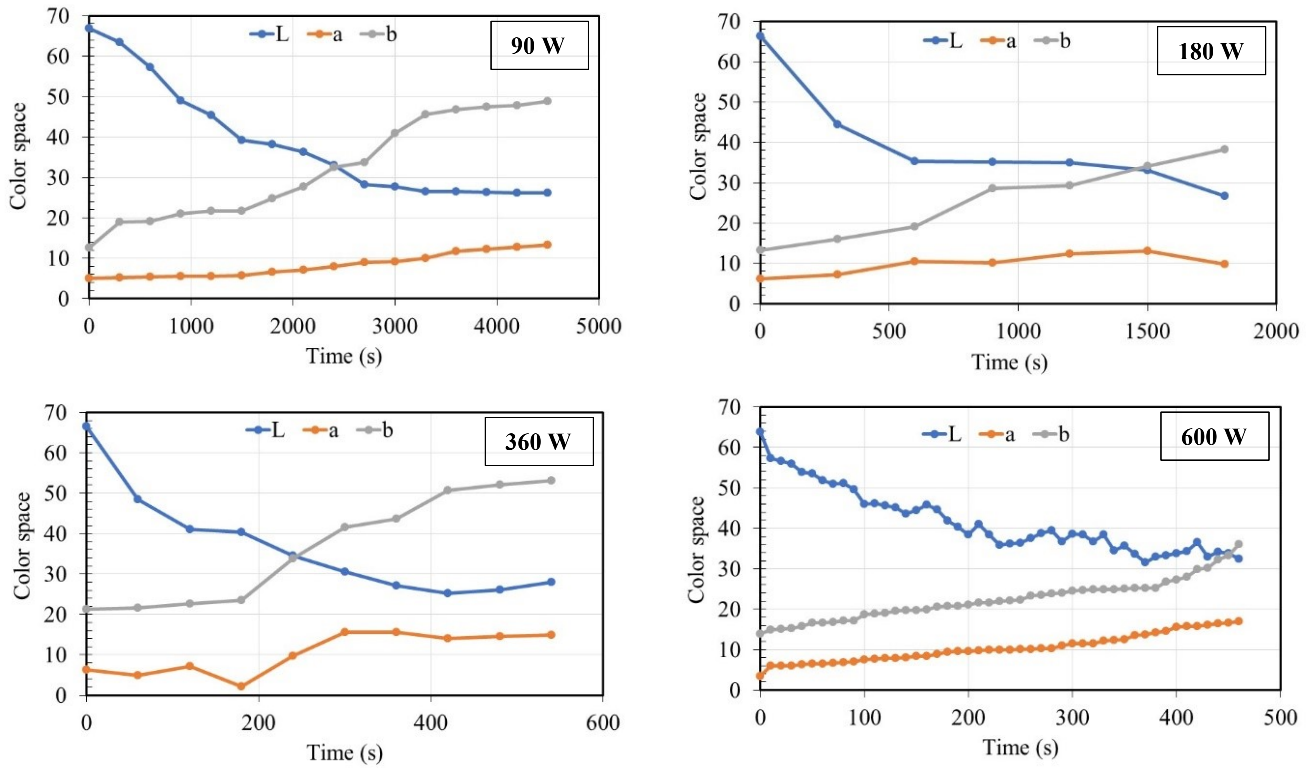

Figure 3. Variation of L*, a* and b* values depending on drying time and drying power values

Figure 5 illustrates the variations in total color and chroma deviations as a function of drying power and drying times. At all drying power levels, total chromatic aberration and chroma aberration were positive. Maximum total chromatic aberration (E) values were achieved at 54.89 and 90 W drying power levels, while minimum values were obtained at 38.04 and 600 W drying power levels. The greatest chroma aberration (C) value was observed at a drying level of 360 W (39.34).

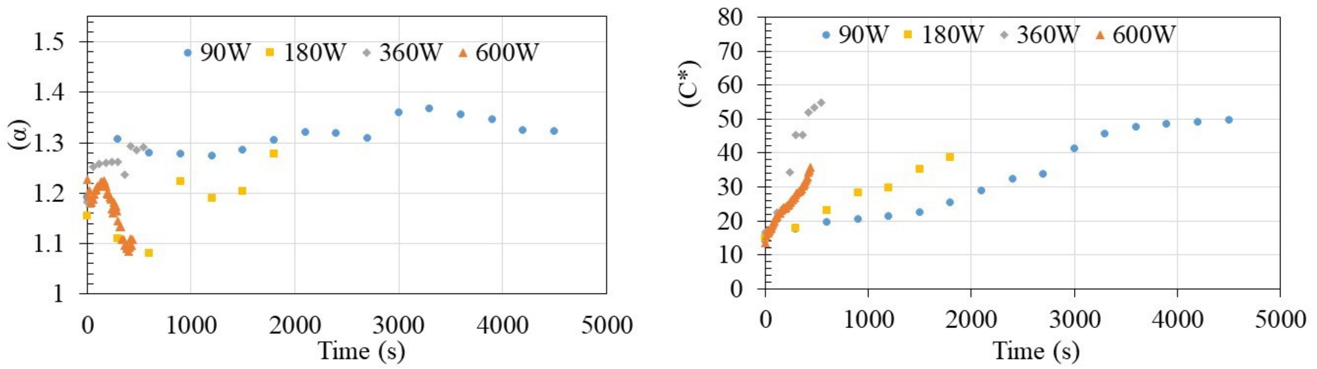

Figure 4. Metric color tones (α) and metric chroma (C*) values of the samples

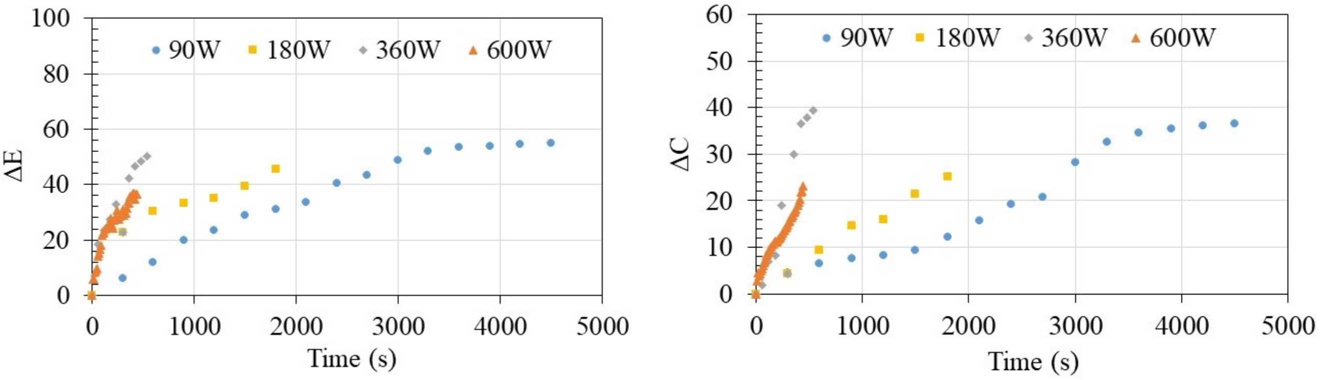

Figure 5. Total chromatic aberration (ΔE), chroma aberration (ΔC) of samples

Table 3. Statistical analysis of color parameters of dried materials

Drying Power	L^*	a^*	b^*	α	C	ΔL	Δa	Δb	ΔE	ΔC
90 W	26.09d	12.17c	48.18b	1.32a	49.69b	-41.59d	6.98c	35.13b	54.89a	36.64b
180 W	27.92c	11.21d	37.12c	1.28b	38.78c	-38.65b	5.19d	23.51c	45.54c	25.17d
360 W	33.82b	15.17b	52.67a	1.29b	54.81a	-32.31c	8.84b	37.20a	50.06b	39.34a
600 W	36.68a	16.59a	34.92d	1.13c	38.66c	-28.36a	12.07a	22.31d	38.04d	26.05c
P	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

All the parameters belong to colour change statistically analyzed and the results are given in Table 3. Multiple comparison tests were applied to the obtained results and the values related to the color parameters were found to be statistically very significant ($p<0.001$).

CONCLUSION

In this study, the color changes of mushrooms dried at four different power levels using the thin slice microwave drying method were investigated, and the following results were obtained.

1. Thinly sliced Oyster mushrooms with an initial moisture content of 93% were dried in a microwave oven at 90 W, 180 W, 360 W, and 600 W power levels until the humidity reached 10.8% in 4500, 1800, 540, and 460 seconds, respectively. Because the achieved humidity level was between 10 and 12% of the humidity values provided in the literature, it was determined that the applied drying method had successfully achieved the desired moisture content.
2. The brightness (L) value decreased from an average of 66.35±1.33 at the start of the drying process to 31.13±5.29 at the end of the drying procedure. On the basis of this number, it can be concluded that the drying process causes the mushrooms' color to darken.

3. The greatest difference in brightness was observed during the drying process at 90 W power. The green-redness (a) value increased from 5.52±0.91 at the start of drying to 13.79±2.69 at the end. The level of red color in the mushrooms' color increased as drying progressed. The blue-yellowness (b) value increased from 13.19±1.43 at the start to 43.22±8.17 at the end of drying. The yellow color component of the mushrooms was observed to increase at the end of the drying process. The greatest difference occurred at 360 W power. Looking at these three components, the mushrooms, which were initially light beige, dried to a brownish color.
4. Both a and b values were positive as a result of drying processes. This indicates that the dried product contains more red and yellow hues than the fresh product.
5. In the study, the highest total chromatic aberration and chroma aberration values were recorded at 90 W and 360 W drying powers, respectively.
6. Due to the extended drying time at 90 W power, it was determined that the color change of the dried product was greater. According to these findings, if the desired humidity level is obtained in a short period of time, there would be less distortion in the product's color changes. However, this should just be viewed as a suggestion for minimizing color change. In drying studies, after assessing the color change of the dried product, drying duration, nutritional content, and shelf life of the final product, the most appropriate drying technique and operating parameters should be chosen.

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Conflict of İnterest

There is no conflict of interest between the authors.

Author's Contributions

The authors declare that they have contributed equally to the article.

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