An Optimization of Moisture Losses and Drying Properties of Orange Peel Reinforcement for Composite Fabrication Using the Taguchi Method

Oluwaseyi Ayodele Ajibade[1], Johnson Olumuyiwa Agunsoye[1] and Sunday Ayoola Oke[2,*]

[1] Department of Metallurgical and Materials Engineering, University of Lagos, Lagos, Nigeria

[2] Department of Mechanical Engineering, University of Lagos, Lagos, Nigeria

*Corresponding author: E-mail address: sa_oke@yahoo.com

Abstract. *Moisture content evaluation is a primary method in the processing and testing of agro-based reinforcement during composite preparation since the moisture content of reinforcement is of direct economic significance to the composite developer. However, its optimization has been of interest to its stakeholders. Unfortunately, the classical Taguchi method which has been extensively applied in the composite industry still suffers some shortcomings, including its heavy reliance on the traditional mean method of averaging values during computations. This unfortunately leads to wrong information and deficiencies in decision making. To conquer these deficiencies, three new methods of averaging, namely, the geometric, harmonic and quadratic means have been proposed. Some evidence has been found that all three alternative means could replace the average method. The harmonic is the best for economic consideration. In addition, for the percentage improvement of optimal values of the parameters, the principal results confirmed that in scenarios 1 to 3, positive results were obtained except scenario 4 when the index comparing the current to the base method was evaluated. Important improvements in composite fabrications and design could be made with the information provided in this for research engineers.*

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1. Introduction

Moisture loss has been a key research focus within the agrophysics and heat transfer research areas for several decades now [1 - 6]. Nevertheless, apricots [1], lemon [3], onion [5], and steam turbines [2] were the case studies referred to by previous researchers. The incentive to investigate agro-product was the economic benefits of dried fruits. These vitamins and protein-rich fruits (products) may be transported in more quantities when dried, leading to greater economic gains. However, the literature has omitted agro-waste, which is dried as reinforcements in composites. These agro-wastes have economic values and are associated with low-cost composites but the literature has not reported on the moisture loss aspect of these agro wastes. Furthermore, in the heat transfer area where moisture loss is studied in steam turbines, the incentive is to understand the projected conditions regarding moisture losses in maintaining wet-steam turbines.

Salehi and Kashaninejad [4] demonstrated success in analyzing the influence of joint infrared-vacuum drying on the kinetics of drying, the diffusivity of moisture, shrinkage and the kinetics of colour transformation of lemons. Although extensive, the authors omitted using the physical properties of weight before and after drying, time and density. Besides, Soleimani Pour-Damanab et al. [3] provided a novel insight into the drying curve mechanism in the baking of bread. The principal factors studied are the baking temperature and the conventional model. While the account given regarding the drying mechanism is useful, the authors omitted the principal factors of weights before and after drying, time and density that are central to moisture loss analysis in reinforcements of composites. Moreover, Islam et al. [5] claimed a framework to assess and analyse the moisture content of onion. The analyzed factors are sizes, weights, temperature and relative humidity. While the choice of initial weight and time, as well as final weight, concurred with the needed factors to analyse the orange reinforcement considered in the present study, the issue of density analysis was ignored in their study. The key conclusion was that electrical impedance parameters are sensitive to the changes of water content in onion. Furthermore, Adeyanju et al. [6] showed the moisture analysis of sliced and fried plantain at various temperatures, including 150, 160, 170, 180 and 190°C. It was reported that the coefficients of correlation between the experimental and predicted values of moisture transfer models were from

0.988 to 0.994. The model was claimed to be consistent in predicting moisture loss of dodo.

Often, in the development of composite structures, green reinforcement and particularly orange peel reinforced composites have taken a great lead as reinforcement in the cost reduction of composites [7 - 18]. For orange peels, several studies have been reported on their mechanical properties, corrosion resistance, electrical insulation properties, rheological properties and more recently their moisture losses. Furthermore, their ultrasonic chemistry, food and products processing and food chemistry have been reported with evidence in the following papers [19 - 25].

However, an aspect of interest in the moisture loss analysis is the optimisation of the process parameters and the utmost parameters may be chosen using several optimisation methods, including genetic algorithm, Taguchi method and particle swarm optimisation among others. Furthermore, among these optimization techniques, the Taguchi method is a widely used optimisation technique for decision making purpose. It has been applied in several fields and real-life developments. The use of the Taguchi method in the moisture loss optimisation process can offer a logical and quantitative method to support decision making in the optimisation of orange peel reinforcement moisture loss before the composite development. The Taguchi method was proposed by Genichi Taguchi to enhance the optimisation outcomes in the moisture loss optimization endeavour. It works based on an ordered procedure of planning carrying out and assessing the results of matrix experiments to establish the utmost degree of control factors. The goal is to reduce the variance from the output to an extremely low value by tacking the noise that distracts the system from utmost performance. By implementing the Taguchi scheme in the moisture loss process of agro-waste, the composite developer is helped to exercise more consistent judgements by considering factor, levels, orthogonal array, limits and optimisation parametric settings.

From the foregoing, the objective of this article is to propose three new methods of averaging the values of the parameters in the moisture loss optimisation process, including the harmonic mean, quadratic mean and geometric mean to challenge the convention arithmetic mean used in computation for several decades. The scope of work for this investigation reported herein was; (1) to study possible moisture loss parameters and to develop an optimisation framework on it based on the Taguchi method for modelling the behaviour of the moisture for orange peels, (2) to devise methods of arriving at the computation of the factor levels and the signal-to-noise (S/N) ratio responses based on geometric, harmonic and quadratic means for alternative decision approach to the arithmetic mean. This will give the opportunity at arriving at an educated decision on what method to use to optimise the outcomes, (3) to devise and establish various base method indices and compare values to the current method indices for value-added decision making.

2. Materials and Methods

2.1 Materials

Orange (Citrus sinensis) is a sweet edible fruit that grows abundantly in different regions and climes of the globe. Its sweet taste, all year round abundant supply and affordability make it the most preferred fruit to people of all classes in society. As a result, its daily consumption is presumably very high all over the world. The main by-product of orange is its peels, which is the greenish-yellow outer layer of orange fruit. When disposed indiscriminately and left to rot, they pollute the environment, and breed germs that can lead to an outbreak of diseases. Thus, the quest to use alternative green fillers in producing improved variety demands of composites makes orange peels a viable choice for green composite production. To this end, orange peels were collected in abundant quantities from local retailers in different parts of Lagos State, Nigeria. Their collection and processing will be discussed in detail in subsequent sections. Subsection Headline.

2.2 Drying Process and Moisture Loss

Drying refers to the removal of moisture or oils from an item, product or system. It has been employed profitably in the production and processing of different kinds of food, dairy products, leather goods [25, 26]. In the current investigation, reference is made to Ajibade et al. [25] that used nine different samples of orange peels. The individual weight of the samples was measured as weight before drying. Each of the samples was spread out in the sunlight in cut-open polyethylene bags. The loss of moisture is characterized by a gradual loss in weight and change in colouration of the orange peels from greenish-yellow to different shades of brown. The drying process starts with the measurement of weight and is completed at sunset with the measurement of weight after drying. The drying of orange peels from sunrise to sunset with the measurement of weights is known as a run. During this process, the time interval of the drying process is also recorded individually for the samples.

The drying and moisture loss process continues with a change in the colouration of the peels and a significant loss in the weight of the individual samples. Drying is said to be complete by visual and physical observation when there is a lack of moisture and oils in the orange peels which makes it crisp. At this stage, the orange peels become dark brown while their shape becomes irregular. Moisture loss is obtained daily from the difference between the weight before drying and weight after drying, while the time taken is calculated from the start of the drying process to the end. The density is calculated using the weight after drying as a mass of the orange peels divided by the measured volume. The measured values of the different parameters in the moisture loss of orange peels could be obtained as follows.

Sample No	Parameters			
	Weight before drying (kg)	Weight after drying (kg)	Time of drying (hrs)	Density of orange peels (g/cm^3)
1	2.25	0.615	82.65000	0.110
2	1.20	0.425	67.78333	0.138
3	1.10	0.340	83.20556	0.113
4	0.30	0.160	67.78333	0.161
5	0.50	0.170	67.78333	0.113
6	0.60	0.210	82.65000	0.108
7	0.25	0.125	67.78333	0.205
8	0.55	0.210	67.78333	0.050
9	1.10	0.390	52.45000	0.204

Table 1 Moisture loss and drying parameters of orange peels

2.3 Design of Experiments

Four important factors have been identified in the moisture loss and drying processes. They are the weight before drying, weight after drying, time of drying and density of the orange peels. Daily monitoring of these factors produced values as described in Table 1. To obtain the ideal moisture loss properties of the orange peels, the moisture loss parameters are being optimised using the Taguchi optimisation method. Traditional experimental design methods involve one factor at a time, where one variable is changed while the rest are kept constant. This turns out to be complex, cumbersome and prohibitive. The major setback of these methods is that it does not take into account interactions between the parameters.

Taguchi method offers a way out of these drawbacks by finding the optimal combination of parameters from the desired response in any given process [27, 28].

The modified Taguchi method involves the following steps:

1. Choosing the response function for the desired quality characteristics and process parameters.
2. Deciding the number of levels for each process parameter and possible interactions between them
3. Using the mean method, involving the bifurcation of the original data values, while the arithmetic means ($\bar{x}$) of the derived data was used to generate the values of parametric levels.
4. Selecting an appropriate orthogonal array.
5. Grouping the S/N ratios by factor level combination in each column of the orthogonal array before obtaining their means.
6. Selecting the optimum level of the process parameters according to the desired quality characteristic.
7. Performing analysis of variance (ANOVA) to find the significant contribution of each parameter.
8. Conducting a confirmatory experiment to verify the results of the ANOVA.

The overall research scheme for the project is shown in Fig. 1.

2.4 Methodology of Means

Means are often used in the determination of parameters levels and the same means are used to obtain the S/N response in the evaluation of the optimal parametric settings for problems considered. The commonly applied mean measures the arithmetic mean of all the values concerned. Let us consider a set of real numbers $k_1,k_2,\ldots k_n$. the arithmetic mean is defined as [29]:

$$m_k = (k_1+k_2+\ldots+k_n)/n \quad (1)$$

For a set of positive numbers,

$$m_g = (k_1\, k_2 k_3\ldots k_n)^{1/n} \quad (2)$$

which represents the geometric mean

Also, for a set of real numbers, the harmonic mean is defined as:

$$m_h = n/({}^1/k_1+ {}^1/k_2+ {}^1/k_3+\ldots\ {}^1/k_n) \quad (3)$$

Again, for a set of n real numbers, $k_1,k_2,\ldots k_n$, the quadratic mean,

$$m_q = ((k_1+k_2+k_3+k_4+\ldots k_n{}^2)/n)^{1/2} \quad (4)$$

where k_n is the number representing the value obtained for the factor-level definition as well as the S/N response values.

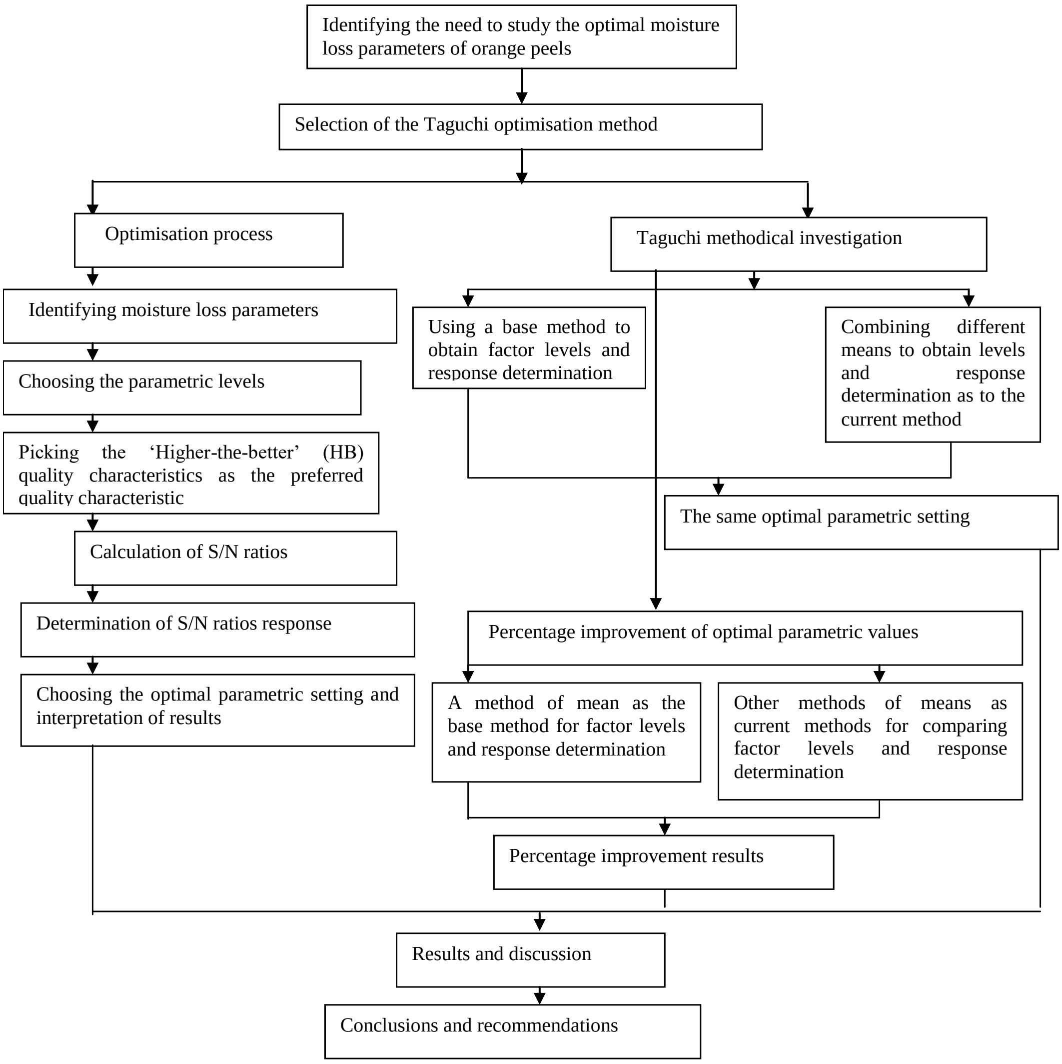

Fig. 1 Research Scheme

To illustrate how the application of the methods was made, we fall back to the original data as described by Table 1. From the mentioned Table 1, using the arithmetic method of computation, add the values 2.250, 1.200 and 1.100 from the second column, second, third and fourth rows. This gives a value of 1.516. This value is written under level 1 but corresponding to "A: weight before drying (g)" in the current paper (Table 1). Note that, this table is referred to as "moisture loss parameters and their levels obtained using "arithmetic mean". Note also that equation (1) is used for the computation. To obtain the value in the cell corresponding to the intersection of row 2, column 3 (under level 2) i.e. 0.467, the values of 0.300, 0.500 and 0.600 under column 2 of the original Table 1 in Ajibade et al. [25] are computed using an arithmetic mean. The procedure is followed to obtain the value under level 3 of parameter A of interest to us. Then, move to parameter B, then parameters C and D. with this, Table 1 in our current paper is obtained. This principle which utilises the arithmetic mean applies to Table 1 of Ajibade et al. [25] is called a method of moisture loss parametric determination and level calculation using the arithmetic mean. The equation used is equation (1).

Also, using equations (2) to (4) and following the same principle of choosing three values and applying geometric, harmonic and quadratic mean principles, tables representing each category may be obtained, as presented in the discussion section of the current paper. Recall that, it was stated that the application of equations (2) to (4) to the determination of factors and levels is novel. Now, the principle of mean evaluations is also applied to the S/N response evaluation. So in any case, there could be a combination of arithmetic, geometric, harmonic and quadratic means for the moisture loss parametric level determination and the S/N ratio response value determination. For this investigation, we use the values of the parametric levels obtained from the arithmetic mean.

Factors	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.516	0.467	0.633
B: Weight after drying (kg)	0.460	0.180	0.242
C: Time (s)	77.879	72.738	62.672
D: Density (g/cm^3)	0.120	0.127	0.153

Table 2 Moisture loss parameters and their levels obtained using the arithmetic mean

Experimental trial	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	3
8	3	2	1	2
9	3	3	2	1

Table 3 L_9 (3^4) orthogonal array

3. Results and Discussions

3.1 Analysis and Discussion

Taguchi's orthogonal array uses the signal-to-noise (S/N) ratio which is a statistical system to measure the performance of the experimental process. The S/N ratios are the logarithmic value of the target response which is the objective function for the optimisation. Three major quality characteristics are being used in the Taguchi method for measuring S/N ratios. They are the "lower-the-better"(LB), the "higher-the-better"(HB) and "nominal-the-best"(NB). Maximum moisture loss is needed in the orange peels to obtain the best drying results within the shortest possible time. Therefore, to obtain the optimal parameters that would yield maximum moisture loss of the orange peels, the "higher-the-better"(HB) quality characteristic is used in this investigation.

$$\text{S/N}(\eta) = -10\log_{10}\left[\frac{1}{n} * \frac{1}{y_i^2}\right] \qquad (5)$$

where n is the number of values at the trial condition and y_i is each observed value.

Experimental trial	A	B	C	D	S/N ratio
1	1.516667	0.460000	77.87963	0.120333	47.89075
2	1.516667	0.180000	72.73889	0.127333	46.16643
3	1.516667	0.241667	62.67222	0.153000	47.94631
4	0.466667	0.460000	72.73889	0.153000	46.16502
5	0.466667	0.180000	62.67222	0.120333	46.16516
6	0.466667	0.241667	77.87963	0.127333	47.88755
7	0.633333	0.460000	62.67222	0.153000	46.16500
8	0.633333	0.180000	77.87963	0.127333	46.16521
9	0.633333	0.241667	72.73889	0.120333	43.93955

Key: A (weight before drying, g), B (weight after drying, g), C (time of drying, s), D (density, g/cm^3)

Table 4 Experimental results for moisture loss parameters

From the literature, it is known that that irrespective of the quality characteristics used, a higher S/N ratio indicates superior quality characteristics. Therefore, the parametric level with the highest S/N ratio is picked as the optimal level for the free swell process. Thus, we have $A_1B_1C_1D_3$ as the optimal parametric setting which would give the desired maximum moisture loss and drying of the orange peels. This translates to weight before drying of 1.516 kg, a weight after drying of 0.46 kg, time of drying of 77.879 hrs and a density of 0.153 g/cm^3.

Parameters	Level 1	Level 2	Level 3
A	47.3345*	46.7392	45.4232
B	46.7402*	46.1656	46.5911
C	47.3145*	45.4236	46.7397
D	45.9984	46.7397	46.7587*

Table 5 S/N response table for moisture loss parameters

Arithmetic method of means for factor levels and geometric method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.5167	0.4667	0.6330	47.3089*	46.7142	45.3936
B: Weight before drying (kg)	0.4600	0.1800	0.2416	46.7152*	46.1479	46.5347
C: Time (hrs)	77.8796	72.7388	62.6722	47.2892*	45.3940	46.7333
D: Density (g/cm^3)	0.1200	0.1270	0.1530	45.9523	46.7147	46.7333*

Arithmetic method of means for factor levels and harmonic method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.5167	0.4667	0.6330	47.3198*	46.7253	45.3986
B: Weight before drying (kg)	0.4600	0.1800	0.2416	46.7262*	46.1656	46.5134
C: Time (hrs)	77.8796	72.7388	62.6722	47.3003*	45.3990	46.7439
D: Density (g/cm^3)	0.1200	0.1270	0.1530	45.9412	46.7258	46.7438*

Arithmetic method of means for factor levels and quadratic method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.5167	0.4667	0.6330	47.3417*	46.7462	45.4353
B: Weight before drying (kg)	0.4600	0.1800	0.2416	46.7473*	46.1656	46.6288
C: Time (hrs)	77.8796	72.7388	62.6722	47.3214*	45.4357	46.7663
D: Density (g/cm^3)	0.1200	0.1270	0.1530	46.0269	46.7476	46.7663*

Table 6 Arithmetic method of means for factor levels and each of geometric, harmonic and quadratic means for S/N ratios response determination.

An optimal parametric setting of $A_1B_1C_1D_3$ was obtained for the Taguchi optimisation of the moisture loss properties of the orange peels. This can be interpreted as weight before drying of 1.5167 kg, weight after drying of 0.46 kg, time of drying 77.8796 hrs and an orange peel density of 0.153 g/cm^3. The results are repeated for all the options of the arithmetic method of means for factor levels and each of geometric, harmonic and quadratic means for S/N ratios response determination.

Geometric method of means for factor levels and arithmetic method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.4374	0.4481	0.5328	47.3345*	46.7392	45.4232
B: Weight before drying (kg)	0.4462	0.1787	0.2171	46.7402*	46.1656	46.5911
C: Time (hrs)	77.5364	72.4151	62.2296	47.3145*	45.4236	46.7333
D: Density (g/cm^3)	0.1197	0.1252	0.1278	45.9984	46.7397	46.7587*

Geometric method of means for factor levels and geometric method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.4374	0.4481	0.5328	47.3089*	46.7142	45.3936
B: Weight before drying (kg)	0.4462	0.1787	0.2171	46.7152*	46.1479	46.5347
C: Time (hrs)	77.5364	72.4151	62.2296	47.2892*	45.3940	46.7333
D: Density (g/cm^3)	0.1197	0.1252	0.1278	45.9523	46.7147	46.7333*

Geometric method of means for factor levels and harmonic method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.4374	0.4481	0.5328	47.3198*	46.7253	45.3986
B: Weight before drying (kg)	0.4462	0.1787	0.2171	46.7262*	46.1656	46.5134
C: Time (hrs)	77.5364	72.4151	62.2296	47.3003*	45.3990	46.7439
D: Density (g/cm^3)	0.1197	0.1252	0.1278	45.9412	46.7258	46.7438*

Geometric method of means for factor levels and quadratic method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.4374	0.4481	0.5328	47.3417*	46.7462	45.4353
B: Weight before drying (kg)	0.4462	0.1787	0.2171	46.7473*	46.1656	46.6288
C: Time (hrs)	77.5364	72.4151	62.2296	47.3214*	45.4357	46.7663
D: Density (g/cm^3)	0.1197	0.1252	0.1278	46.0269	46.7467	46.7663*

Table 7 Geometric method of means for factor levels and each of geometric, harmonic and quadratic means for S/N ratios response determination

Harmonic method of means for factor levels and harmonic method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.3718	0.4285	0.4459	47.3198*	46.7253	45.3986
B: Weight before drying (kg)	0.4335	0.1775	0.1957	46.7262*	46.1656	46.5134
C: Time (hrs)	77.1792	72.1067	61.7645	47.3003*	45.3990	46.7439
D: Density (g/cm^3)	0.1191	0.1233	0.1007	45.9412	46.7258	46.7438*

Harmonic method of means for factor levels and arithmetic method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.3718	0.4285	0.4459	47.3345*	46.7392	45.3986
B: Weight before drying (kg)	0.4335	0.1775	0.1957	46.7402*	46.1656	46.5911
C: Time (hrs)	77.1792	72.1067	61.7645	47.3145*	45.4236	46.7588
D: Density (g/cm^3)	0.1191	0.1233	0.1007	45.9984	46.7397	46.7587*

Harmonic method of means for factor levels and geometric method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.3718	0.4285	0.4459	47.3089*	46.7142	45.3936
B: Weight before drying (kg)	0.4335	0.1775	0.1957	46.7152*	46.1479	46.5347
C: Time (hrs)	77.1792	72.1067	61.7645	47.2892*	45.3940	46.7333
D: Density (g/cm^3)	0.1191	0.1233	0.1007	45.9523	46.7147	46.7333*

Harmonic method of means for factor levels and quadratic method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.3718	0.4285	0.4459	47.3417*	46.7462	45.4353
B: Weight before drying (kg)	0.4335	0.1775	0.1957	46.7473*	46.1656	46.6288
C: Time (hrs)	77.1792	72.1067	61.7645	47.3214*	45.4357	46.7663
D: Density (g/cm^3)	0.1191	0.1233	0.1007	46.0269	46.7467	46.7663*

Table 8 Harmonic method of means for factor levels and each of geometric, harmonic and quadratic means for S/N ratios response determination

The optimal parametric setting for the Taguchi optimisation of moisture loss properties was obtained as $A_1B_1C_1D_3$. This can be translated as weight before drying of 1.437 kg, weight after drying of 0.446 kg, time of drying of 77.536 hrs and a density of 0.128 g/cm^3. The results are repeated for all the options of the geometric method of means for factor levels and each of arithmetic, harmonic and quadratic means for S/N ratios response determination.

The optimum setting of the parameters for the Taguchi optimisation of moisture loss characteristics was obtained as $A_1B_1C_1D_3$ which reads as weight before drying of 1.371 kg, weight after drying of 0.433 kg, a time of drying of 77.179 hrs and a density of 0.101 g/cm^3.

The optimum setting of the parameters for the Taguchi optimisation of moisture loss characteristics was obtained as $A_1B_1C_1D_3$ which reads as weight before drying of 1.3178 kg, weight after drying of 0.4335 kg, a time of drying of 77.1792 hrs and a density of 0.1007 g/cm^3. The results are repeated for all the options of the geometric method of means for factor levels and each of arithmetic, harmonic and quadratic means for S/N ratios response determination.

The Taguchi optimisation of the moisture loss properties of orange peels produced an optimum parameter setting of $A_1B_1C_1D_2$ which can be taken as weight before drying of 1.603 kg, a weight after drying of 0.474 kg, a time of drying of 78.206 hrs while the density was obtained as 0.09 g/cm^3.

Quadratic method of means for factor levels and harmonic method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.6033	0.4509	0.7245	47.3198*	46.7253	45.3986
B: Weight before drying (kg)	0.4741	0.1559	0.2657	46.7262*	46.1656	46.5134
C: Time (hrs)	78.2064	61.7133	63.087	47.3003*	45.3990	46.7439
D: Density (g/cm^3)	0.1209	0.090	0.1694	45.9412	46.7258*	46.7438

Quadratic method of means for factor levels and arithmetic method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.6033	0.4509	0.7245	47.3345*	46.7392	45.4232
B: Weight before drying (kg)	0.4741	0.1559	0.2657	46.7402*	46.1656	46.5911
C: Time (hrs)	78.2064	61.7133	63.087	47.3145*	45.4236	46.7588
D: Density (g/cm^3)	0.1209	0.090	0.1694	45.9984	46.7397*	46.0169

Quadratic method of means for factor levels and geometric method of means for S/N ratios response determination

	Moisture loss parametric levels			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.6033	0.4509	0.7245	47.3089*	46.7142	45.3936
B: Weight before drying (kg)	0.4741	0.1559	0.2657	46.7152*	46.1479	46.5347
C: Time (hrs)	78.2064	61.7133	63.087	47.2892*	45.394	46.7333
D: Density (g/cm^3)	0.1209	0.090	0.1694	45.9523	46.7147*	45.9700

Quadratic method of means for factor levels and quadratic method of means for S/N ratios response determination

	Moisture loss parametric level			S/N response		
Parameters/factors	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
A: Weight before drying (kg)	1.6033	0.4509	0.7245	47.3417*	46.7462	45.4353
B: Weight before drying (kg)	0.4741	0.1559	0.2657	46.7473*	46.1656	46.6288
C: Time (hrs)	78.2064	61.7133	63.087	47.3214*	45.4357	46.7663
D: Density (g/cm^3)	0.1209	0.090	0.1694	46.0269	46.7467	46.7663*

Table 9 Quadratic method of means for factor levels and each of geometric, harmonic and quadratic means for S/N ratios response determination

The combination of a particular mean as a base method to obtain the factor levels and other means to determine the average S/N ratios was found to produce the same optimal parametric setting and results as shown in Tables 6 to 9. These results were further summarized in Table 10. In other words, the interpretation of the optimal parametric setting indicates that the base method and the different current methods produced the same optimal results of the moisture loss parameters. A further basis of comparison was to find the percentage improvement of each parameter's optimal value using each of the methods as a base method while the other optimal values of other methods as the current methods in Table 11. This produced four different scenarios, where the percentage improvement of each parameter optimal value is zero on the base method and an obtained value in the current methods.

In scenario 1, the percentage improvement of the optimal value is calculated using the arithmetic mean as the base method, while the optimal value of parameters in other methods is used as the current methods. The weight before drying produced a negative improvement of -0.05 and -0.09 % for the *MgLF-MgR* and *MhLF-MhR* methods, respectively. This shows that the two methods of calculating the mean produced optimal values of the weight before drying which is less than that obtained using the arithmetic mean. On the other hand, the *MqLF-MqR* method produced a percentage improvement for the optimal value of weight before drying which signifies that it is higher than that obtained by the *MaLF-MaR*. The same trend was found in the percentage improvement of weight after drying and time of drying. The *MgLF-MgR* and *MhLF-MhR* produced negative percentage improvements in the optimal values of both parameters. Again, the *MqLF-MqR* has a slight improvement of 0.004 %. The case was

S/N	Parameters	Base method index	Current method index	Current method index	Current method index
		Dataset 1			
		(MqLF-MqR)	(MqLF-MaR)	(MqLF-MgR)	(MqLF-MhR)
1	Weight before drying (kg)	1.6033	1.6033	1.6033	1.6033
2	Weight after drying (kg)	0.4741	0.4741	0.4741	0.4741
3	Time of drying (s)	78.2064	78.2064	78.2064	78.2064
4	Density (g/cm^3)	0.090	0.090	0.090	0.090
		Dataset 2			
		(MhLF-MhR)	(MhLF-MaR)	(MhLF-MgR)	(MhLF-MqR)
1	Weight before drying (kg)	1.3718	1.3718	1.3718	1.3718
2	Weight after drying (kg)	0.4335	0.4335	0.4335	0.4335
3	Time of drying (s)	77.1792	77.1792	77.1792	77.1792
4	Density (g/cm^3)	0.1191	0.1191	0.1191	0.1191
		Dataset 3			
		(MgLF-MgR)	(MgLF-MaR)	(MgLF-MhR)	(MgLF-MqR)
1	Weight before drying (kg)	1.4374	1.4374	1.4374	1.4374
2	Weight after drying (kg)	0.4462	0.4462	0.4462	0.4462
3	Time of drying (s)	77.5364	77.5364	77.5364	77.5364
4	Density (g/cm^3)	0.128	0.128	0.128	0.128
		Dataset 4			
		(MaLF-MaR)	(MaLF-MgR)	(MaLF-MhR)	(MaLF-MqR)
1	Weight before drying (kg)	1.5167	1.5167	1.5167	1.5167
2	Weight after drying (kg)	0.46	0.46	0.46	0.46
3	Time of drying (s)	77.8796	77.8796	77.8796	77.8796
4	Density (g/cm^3)	0.153	0.153	0.153	0.153

Note:
MqLF-MqR: quadratic mean describing factor levels-quadratic mean response
MqLF-MaR: quadratic mean describing factor levels-arithmetic mean response
MqLF-MgR: quadratic mean describing factor levels-geometric mean response
MqLF-MhR: quadratic mean describing factor levels-harmonic mean response
MhLF-MhR: harmonic mean describing factor levels-harmonic mean response
MhLF-MaR: harmonic mean describing factor levels-arithmetic mean response
MhLF-MgR: harmonic mean describing factor levels-geometric mean response
MhLF-MqR: harmonic mean describing factor levels-quadratic mean response
MgLF-MgR: geometric mean describing factor levels-geometric mean response
MgLF-MaR: geometric mean describing factor levels-arithmetic mean response
MgLF-MhR: geometric mean describing factor levels-harmonic mean response
MgLF-MqR: geometric mean describing factor levels-quadratic mean response
MaLF-MaR: arithmetic mean describing factor levels-arithmetic mean response
MaLF-MgR: arithmetic mean describing factor levels-geometric mean response
MaLF-MhR: arithmetic mean describing factor levels-harmonic mean response
MaLF-MqR: arithmetic mean describing factor levels-quadratic mean response

Table 10 Base and current method comparison

S/N	Parameters	Base method index (MaLF-MaR)	Current method index (MgLF-MgR)	Current method index (MhLF-MhR)	Current method index (MqLF-MqR)
		Percentage improvement (%)			
Scenario 1: Percentage improvement using Arithmetic mean for factor levels and responses as the base method					
1	Weight before drying (kg)	0	-0.050	-0.09	0.05
2	Weight after drying (kg)	0	-0.030	-0.06	0.03
3	Time of drying (s)	0	-0.004	-0.008	0.004
4	Density (g/cm^3)	0	-0.164	-0.221	-0.411
Scenario 2: Percentage improvement using Geometric mean for factor levels and responses as the base method					
		MgLF-MgR)	(MaLF-MaR)	(MhLF-MhR)	(MqLF-MqR)
1	Weight before drying (kg)	0	0.055	-0.04	0.115
2	Weight after drying (kg)	0	0.029	-0.028	0.063
3	Time of drying (s)	0	0.004	-0.004	0.008
4	Density (g/cm^3)	0	0.197	-0.068	-0.2957
Scenario 3: Percentage improvement using Harmonic mean for factor levels and responses as the base method					
		(MhLF-MhR)	(MaLF-MaR)	(MgLF-MgR)	(MqLF-MqR)
1	Weight before drying (kg)	0	0.105	0.047	0.168
2	Weight after drying (kg)	0	0.061	0.029	0.093
3	Time of drying (s)	0	0.009	0.0046	0.013
4	Density (g/cm^3)	0	0.2846	0.073	-0.2443
Scenario 4: Percentage improvement using Quadratic mean for factor levels and responses as the base method					
		(MqLF-MqR)	(MaLF-MaR)	(MgLF-MgR)	(MhLF-MhR)
1	Weight before drying (kg)	0	-0.054	-0.1034	-0.178
2	Weight after drying (kg)	0	-0.029	-0.058	-0.085
3	Time of drying (s)	0	-0.004	-0.008	-0.013
	Density (g/cm^3)	0	0.7	0.42	0.323

Table 11 Scenarios 1 to 4: Percentage improvement using a method of means for factor levels as base method and other methods of means as the current method

however different for the density parameter, with all the comparative methods producing negative percentage improvement results. The lowest percentage improvement was by the *MqLF-MqR* method, which indicates that the optimal value of density obtained by this method, is lesser than what was derived using the *MaLF-MaR*. These percentage improvements in practical terms imply that a lesser amount of resources can be utilised using the *MgLF-MgR* and *MhLF-MhR*, while a higher amount of resources are consumed using the *MqLF-MqR* method, except in the case of the density parameter.

In scenario 2, the *MgLF-MgR* was used as the base method while the other methods were used as current methods to obtain the percentage improvements on the optimal values of the parameters. A percentage improvement of 0.055, 0.029, 0.004 and 0.197 % respectively, was obtained for the four parameters using the *MaLF-MaR* for comparison. Again, this shows that the *MgLF-MgR* can be more economical in obtaining optimal values of scarce resources in comparison to the conventionally used *MaLF-MaR*. The *MhLF-MhR* produced a negative improvement of -0.04, -0.028,-0.004 and -0.068 % for the four parameters, respectively. In other words, the optimal values obtained using the *MhLF-MhR* is less than the values obtained using the base *MgLF-MgR* method. This also signifies that the *MhLF-MhR* can be used to obtain optimal values in scarce resources. However, the *MqLR-MqR* gave positive percentage improvements in all the parameters except in density. This implies that the optimal values produced by the *MqLR-MqR* method are comparatively higher than those obtained by the *MgLF-MgR* method, except for the density parameter.

For scenario 3, the *MhLF-MhR* serves as the base method, while the other methods were used for comparative purposes. The *MaLF-MaR* gave positive percentage improvements of 0.105, 0.061, 0.009 and 0.2846 %, respectively for all the moisture loss parameters. Likewise, the *MgLF-MgR* produced a percentage improvement of 0.047, 0.029, 0.0046 and 0.073 % for the parameters. This again shows that comparatively, the optimal results obtained using the *MhLF-MhR* are more economical in managing scarce resources. The *MqLR-MqR* obtained the highest percentage improvement in the optimal values of the parameters for the three methods compared in scenario 3. However, it recorded a negative percentage improvement of -0.2443 for the optimal value of density.

In the last scenario, the *MqLR-MqR* was used as the base method, while the other methods were used as the current methods. It was observed that all the other methods had negative percentage improvements for the weights before and after drying as well as the time of drying. They however produced positive percentage improvements of 0.7, 0.42 and 0.323 % for the density parameter for the *MaLF-MaR*, *MgLF-MgR* and *MhLF-MhR*, respectively. These comparative results indicate that the optimal value obtained by the three methods can be more judicious in managing scarce resources when compared to the *MqLR-MqR*.

Of the four methods of means that were used to obtain the factor levels and response determination, it is safe to deduce that the *MhLF-MhR* can be used to obtain the most economic results of the parameters in the face of scarce resources. This is because, in scenarios 1, 2 & 4, the *MhLF-MhR* obtained a lower percentage improvement of the optimal values of the parameters compared to the remaining methods. In scenario 3, where the *MhLF-MhR* was used as the base method, all the current methods produced a positive percentage improvement of the parameters. This signifies that the amount of resources expendable using any of these optimisation methods is more than that which could be used using the *MhLF-MhR* method. Therefore, the optimal values of the parameters obtained using the harmonic method of means are preferable when considering the economic and judicious use of resources.

To summarise the results obtained from the study, the following is noted. The traditional arithmetic mean and three innovative mean methods, quadratic, harmonic and geometric means were used for factors-levels and response determination Using the traditional arithmetic mean for factors-levels and response determination, the optimal results were in the order $A_1B_1C_1D_3$ which translates to 1.516 kg weight before drying, 0.46 kg weight after drying, 77.879 hrs time of drying and a density of 0.153 g/cm^3. In applying the geometric mean, the optimal results were in the order $A_1B_1C_1D_3$ which interprets as 1.4371 kg weight before drying, 0.446 kg weight after drying, 77.536 hrs time of drying and a density of 0.128 g/cm^3. For the harmonic mean, the optimal result was in the order $A_1B_1C_1D_3$ which reads as 1.371 kg weight before drying, a weight of drying 0f of 0.433 kg, time of drying of 77.179 hrs and a density of 0.101 g/cm^3. For the quadratic mean, the optimal results were in the order $A_1B_1C_1D_2$ which can be understood as 1.603 kg, a weight after drying of 0.474 kg, a time of drying of 78.206 hrs and a density of 0.09 g/cm3. In applying the geometric, harmonic and quadratic mean method of means, the orders $A_1B_1C_1D_3$, $A_1B_1C_1D_3$, $A_1B_1C_1D_2$, respectively. This indicates that the arithmetic, geometric and harmonic method of means exhibited the same optimal parametric setting but different results which are the obtainable values for the desired “higher-the-better” (HB) quality characteristics. For the percentage improvement of optimal values of the parameters, the *M*q*LF*-*M*q*R* is the only method of mean that did not give negative percentage improvement in scenario 1 except for the density parameters. In scenario 2, only the *M*h*LF*-*M*h*R* did not give positive percentage improvements for all the parameters, while the *M*a*LF*-*M*a*R* and *M*q*LF*-*M*q*R* produced negative percentage improvements for the density parameter alone. In scenario 3, all the current methods resulted in positive percentage improvements except for *M*q*LF*-*M*q*R* which recorded a negative percentage improvement for the density parameter. Lastly in scenario 4, all the current methods recorded negative percentage improvements for all the parameters except for density.

The results, which compare the current approach with the literature demonstrates the effectiveness and reliability of the proposed approach. In sum, the main strengths of the current study are declared in the following issues:

(1) In comparison with related literature on moisture losses of orange peels, the proposed approach utilises an optimisation method to solve the problems of evaluating the moisture losses. From the literature related to moisture losses in general [26] and the specific one on orange peels Ajibade et al. [25], several indices are used, such as moisture contact at the time, moisture ratio, drying rate, total energy for drying and re-hydration index. Although these indices are useful, they appear not to represent the true state of moisture loss for the orange peels. The design and fabrication engineer is interested in the optimal thresholds of moisture loss parameters such as the weight before and after drying as well as the time taken to achieve drying while the density of the orange peels at that time should be optimally determined. The simple reason for this is that the knowledge of these optimal values is required for the simulation purposes of the interaction between the orange peel particulate fillers together with other fillers such as coconut shell particulates to be determined in their mixtures. This fact is the principal difference that separates the current investigation from the literature related to moisture losses on orange peels.

(2) In comparison with other optimisation methods, the Taguchi technique utilised offers numerous benefits. In the first instance, the Taguchi technique saves tremendous costs of experimentation as the number of experiments required to make valid conclusions significantly reduces compared to methods such as particle swarm optimisation, bee colony optimisation among the non-traditional optimisation techniques and goal programming, integer programming and linear programming among the traditional programming techniques. In the second instance, the Taguchi method has the record of simplicity in computations. The cumbersome calculations that the aforementioned alternative optimisation techniques have is avoided as even spreadsheets such as Microsoft Excel could be comfortably adapted for use with the Taguchi method. This is not the case for other mentioned optimisation methods. Thus, the proposed method is far less demanding in terms of computational power and time to carry out a decision from the viewpoint of mathematical analysis.

(3) By comparing the current paper with other optimisation studies, this work brings a new perspective to the determination of factors and levels as well as S/N ratio responses, using the geometric, harmonic and quadratic means. From the literature related to the Taguchi method, the traditional approach to the evaluation of the factors and levels as S/N ratio responses has been the arithmetic mean method. As a deviation from the traditional approach, the three new methods introduced are supposed to provide alternatives, provoking those insides and possibly those outsides, the physical property analytical community to see how factors and level and S/N ratio responses could be computed differently. By this, a wider choice of alternatives will bring scientific excitement to the frontier of knowledge.

(4) Based on a comparison with established results in the literature, the current paper introduces the concept of base and current methods with which analysis of deviations in performance between or among two or more mean evaluation methods could be measured. Wide deviations could stimulate probes into the effectiveness of each mean evaluation approach.

3.2 Practical Implication

Despite the disparity in the values of the parameters and the peculiarities of each moisture loss and drying experiment, the current study has been able to find the optimal combination of parameters to produce the best moisture loss and drying properties of the orange peels. The weight of the individual orange peel sample before drying ranged from 0.25 to 2.25 kg, while the weight after drying spanned from 0.125 to 0.615 kg. The time of drying also varied from sample to sample from 52.45 to 83.2056 hrs. As a result, different densities were obtained due to the individual measures of mass and volume.

For an engineer, who needs to make shrewd decisions on the choice of individual sample with the best moisture loss and drying properties for processing as fillers for composite production, such a decision cannot be obtained by intuition but by the scientific method of optimisation. Thus, the values are bifurcated and arithmetic mean was used to obtain the parametric values describing the factors before using the Taguchi optimisation method. The optimal value of the weight before drying was found to be 1.5167 kg which is less than the peak of 2.25 kg. This implies that some amount of orange peels can be saved in terms of material weight before spreading them in open sunlight. This would ensure judicious use of resources amid harsh economic conditions. The optimal weight after drying is obtained as 0.467 kg indicates that a considerable moisture loss of 1.049 kg was achieved from the optimisation of the parameters. From the collected data, the optimal weight after drying of 0.467 kg indicates a relatively high amount of moisture loss from a weight of 1.5167 which compares favourably with 0.615 from 2.25 kg and 0.425 from 1.2 kg in samples 1 and 2, respectively.

The optimal drying time of 77.87 hrs is found to be relatively less than the highest values obtained from the collected data. The peak drying time was found as 83.20 hrs from a mass of 1.1 kg followed closely by 82.65 from 2.25 kg weight before drying, for samples 3, 1, and 6 respectively. Thus, the use of optimisation has led to good moisture loss and drying within a time that is economic for production. The optimal density value of the orange peels was found to be 0.153 g/cm^3, lesser than the peak value from the collected data and is relatively low enough for processing into useful low-density in-demand composites.

3.3 Summary of Findings

Taguchi optimisation results:

The following can be deduced from the optimisation of moisture loss and drying properties of orange peels. The optimisation of the moisture loss properties was carried out using the Taguchi optimisation method's "Higher-the-better" (HB) quality characteristic based on the L_9 orthogonal array.

- The Taguchi optimal parametric setting for the moisture loss and drying properties of orange peels is $A_1B_1C_1D_3$. This can be interpreted as 1.5167 kg weight before drying, 0.467 kg weight after drying, a time of drying of 77.8796 hrs and a density of 0.153 g/cm^3.
- The optimal value of the weight before drying is 1.5167 kg which is less than a maximum value of 2.25 kg from the original data. This shows that a substantial saving of the materials can be made amid scarce resources.
- The optimal value of weight after drying is 0.467 kg which indicates that considerable moisture loss was achieved from a weight before drying of 1.5167 kg. This compares favourably with 0.615 from 2.25 kg and 0.425 from 1.2 kg in the original data.
- The optimal time of drying was obtained as 77.8796 hrs which compares favourably with 82.65 hrs from a sample size of 2.25 kg and 83.2056 hrs from a sample size of 1.1 kg.
- The optimal density of orange peels was obtained as 0.153g/cm3 which compares favourably with 0.161 g/cm3 from a sample size of 0.3 kg and a 0.204 g/cm3 from a sample size of 1.1 kg.

Mean method of value determination:

The following submissions can be made from the use of a mean as a sole method of obtaining the factor levels and the responses of the S/N ratios and a combination of different means to obtain the factor levels and S/N ratio responses.

- The optimal parametric setting of moisture loss parameters of orange peels using the arithmetic mean as a base method and a combination of the arithmetic mean and other methods were found to be the same as $A_1B_1C_1D_3$. This translates to 1.5167 kg weight before drying, 0.46 kg weight after drying, 77.8796 hrs time of drying and a density of 0.153 g/cm^3.
- The optimum parametric setting of moisture loss parameters of orange peels using the geometric mean as a base method as well as a combination of the geometric mean and other means gave the same result of $A_1B_1C_1D_3$. This translates to weight before drying of 1.4374 kg, a weight after drying of 0.4462 kg, a time of drying of 77.5364 hrs and a density of 0.1278 g/cm^3.
- The use of the harmonic mean as a base method and with a combination of other means produces the same optimal parametric setting of $A_1B_1C_1D_3$, which is interpreted as 1.3718 kg weight before drying, 0.4335 kg weight after drying, a time of drying of 77.1792 hrs and a density of 0.1009 g/cm^3.
- The optimal parametric setting of moisture loss parameters of orange peels using the quadratic mean as a base method and a combination of the quadratic mean and other means obtained the same setting of $A_1B_1C_1D_2$. This can be translated as

weight before drying of 1.6033 kg, a weight after drying of 0.4741 kg, time of drying of 78.2064 hrs and a density of 0.09 g/cm^3.

Comparative analytical results:

The following deductions were made from the percentage improvements of the optimal value of the moisture loss parameters by comparing the results from other mean methods with the results from a base method.

- In scenario 1, the *MaLF-MaF* is the base method while the others are used as comparative methods. Only the *MqLF-MqF* did not give percentage improvement except in the density parameter with a percentage improvement of -0.411 %.
- In scenario 2, the *MgLF-MgR* is the base method while others are used as comparative methods. The *MaLF-MaF* and *MqLF-MqF* produced positive percentage improvements for the parameters except for density. The *MhLF-MhF* however gave negative percentage improvements for all the parameters.
- The *MhLF-MhF* was used as the base method in scenario 3 making the other methods comparative. All the comparative methods gave positive percentage improvements for all the parameters. However, the *MqLF-MqF* produced a negative percentage improvement for the density parameter.
- In scenario 4, the *MqLF-MqF* was used as the base method. All the comparative methods gave negative percentage improvements for all the parameters. On the contrary, positive percentage improvements were recorded for the density parameter across all the comparative methods.
- The *MhLF-MhR* was found to be the most preferred method of means for obtaining optimal results amid scarce economic resources.

4. Conclusions

The paper has presented a detailed account of Taguchi methodical application to the moisture loss behaviour of orange peels used as orange fillers in polymer composite design, development, fabrication and use. The determination of factors levels on hand, and that of S/N ratio responses, on the other hand, was made using a combination of mean approaches, namely the geometric, harmonic, quadratic and arithmetic mean, which is the traditional framework used in the evaluation. The several combinations were subjected to performance evaluation, using a method as reference (base) while the second was chosen as the current method. This aided our understanding of how the factors levels, as well as the S/N ratio response, changed for different optimal settings. Based on the observations and understanding from the analysis carried out, the principal conclusion made concerning the work is that the harmonic method is the best for economic consideration.

The obtained results could serve as a guide for material selection for engineers who desires the best moisture loss properties when faced with similar data. Having initiated Taguchi methodical research on moisture loss in a new direction, the current study has succeeded in increasing our understanding of moisture loss Taguchi methodical optimisation. However, the study could be extended to study the effects of an increase in the number of parameters on the optimal setting outputs. A further direction of research is in the variations of orthogonal arrays to observe the most sensitive ones to the problem being solved.

References

[1] G. Miranda, A. Berna, A. Bone, A. Mulet, "Modeling of the process of moisture loss during the storage of dried apricots, " *Food Science and Technology International*, vol.17, no. 5, 2011, pp. 439-447.

[2] H. Kawagishi, A. Onoda, N. Shibukawa, Y Niizeki, "Development of moisture loss models in steam turbines," *Heat Transfer*, vol. 42, no. 7, 2013, pp.651-664.

[3] A. R. Soleimani Pour-Damanab, A. Jafary and S. Rafiee, "Determination of suitable drying curve model for bread moisture loss during baking," *International Agrophysics*, vol.27, 2013, pp. 233-237, DOT: 102478/v/0247-012-0090-y.

[4] F. Salehi, M. Kashaniejad, "Modeling of moisture loss kinetics and colour changes in the surface of lemon slice during the combined infrared vacuum drying," *Information Processing in Agriculture*, vol.5, no.4, 2018, pp.516-523.

[5] M. Islam, K. A. Wahid, A. V. Dinh and P. Bhowmik, "Model of dehydration and assessment of moisture content on onion using EIS," *Journal of Food Science and Technology* vol.56, 2019, pp.28142824, Dot: 10.1007/s13197-019-03590-3.

[6] J. A. Adeyanju, J. O. Olajide, E. O. Oke and A. A. Adedeji, "Modelling of moisture loss and oil uptake during deep-fat frying of plantain (dodo)," *Arid Zone Journal of Engineering, Technology and Environment*, vol. 14, 2020, pp. 51-61.

[7] B. V. Kokta, R. G. Roy and C. Daneault, "Use of wood flour as filler in polypropylene: studies on mechanical properties," *Polymer Plastic Technology*, vol. 28, 1989 pp. 247-259.

[8] M. M. Sain, J. Balatinecz, S. Law, "Creep Fatigue in Engineered Wood Fibres and Plastic Composites," *Journal of Applied Polymer Science*, vol. 77, no. 23, 2000, pp. 260-268.

[9] M. Sain, S. Law, F. Suhara and A. Boullinox, "Stifness correlation of natural fibre filled polypropylene composites," *Proceedings of Wood Fibre Polymer Composites Symposium*, 2003, pp. 25-27.

[10] S. Panthapulakkal and M. Sain, "Enhancement of processability of rice husk filled-high density polyethylene composite," *Journal of Thermoplastic Composite Materials*, vol. 18, no. 5, pp. 445-459, 2005.

[11] M. S. Saleman and A. S. Luyt, "Thermal and Mechanical properties of Polypropylene-Wood Powder Composites," *Journal of Applied Polymer Science*, vol. 100, no. 67, pp. 4173-4180, 2006.

[12] S. Ochi, "Mechanical properties of kenaf fiber and kenaf/pla

composites," *Mechanical Materials*, vol. 40, 2008, pp. 446-452.

[13] S.M.L. Rosa, S.M.B Nachtigall and C.A Ferreira, "Thermal and dynamic mechanic characteristics of rice husk filled polypropylene composites," *Macromol. Res.*, vol. 17, no. 1, 2009, pp. 8-13.

[14] B. Dimzoski, G. Bogoeva-Gacva, G. Gentile, M. Avella and A. Grozdanor, "Polypropylene-based eco-composites filled with agricultural rice husk waste," *Chemical and Biochemical Engineering Quarterly*, vol. 23, no. 2, 2009, pp. 225-230.

[15] W. A. Rahman, T. S. Lee, A. R. Rahmatt, N. M. Isa, M. S. N. Salleh and M. Mokhtar M., "Comparison on rice husk filled poly ethylene composite and natural wood under weathering effects," *Journal of Composite Materials*, vol. 45, no. 13, 2011, pp. 1403-1411.

[16] M. M. Kabir, H. Wang, K. T. Lau, F. Cardona and T. Aravinthan, "Mechanical properties of chemically-treated hemp fibre reinforced sandwich composites," *Composites Part B: Engineering*, vol. 43, 2011, pp. 159-169.

[17] A. H. Abdullab, S. K. Alias, N. Jenaf, K. Abdan and A. Ah., "Fatigue behaviour of kenaf fibre reinforced epoxy composite," *Engineering Journal*, vol. 16, no. 5, 2012, pp. 105-113.

[18] A. Getu and O. Sahu, "Green composite material from agricultural waste," *International Journal of Agricultural Research and Review*, vol. 2, no. 5, 2014, pp. 65-62.

[19] J. D. Vera, R. F. Matthews, P. G. Crandall and R. Cook, "Preparation and chemical composition of orange oil concentrates," *Journal of Food Science*, vol. 48, no.4, 1983, pp. 1197 – 1197.

[20] J. Pino, M. Sarchez, R. Sanchez and E. Rocal, "Chemical composition of orange oil concentrates," *Nahrung/Food*, vol. 36, no. 6, 2006, pp. 539-542.

[21] S. Ojha, G. Regharendra, S. K. Acharya and P. Kumar, "Fabrication and study of mechanical properties of orange peel reinforced polymer composite," *Caspain Journal of Applied Sciences Research*, Vol. 1, No. 13, 2012, pp. 190-192.

[22] S. T. Kumar, "Mechanical behaviour of orange peel reinforced epoxy composite, Unpublished B. Tech. Project," *Department of Mechanical Engineering, National Institute of Technology, Rourkela, India*, 2012.

[23] V. S. Aigbodion, C. U. Atuanya, E. A. Igogori and P. Ihom, 2013, "Development of high-density polyethylene/orange peels particulate bio-composite," *Gazi University Journal of Science*, vol. 26, no. 1, 2013, pp. 107-117.

[24] O. A. Ajibade, J. O. Agunsoye and S. A. Oke, "Analysis of the free-swell behaviour of orange peel particulates as reinforcement for green composite fabrication," *Acta Periodica Technologica*, vol. 46, 2015, pp. 131-147

[25] O. A. Ajibade, J. O. Agunsoye and S. A. Oke, S.A. 2015, "Experimentation and prediction of moisture characteristics and density of sweet orange peels used for epoxy-based composite fabrication," *Journal of The Association of Professional Engineers of Trinidad and Tobago*, vol. 43, no. 2, October, 2015, pp. 44-52.

[26] T. Y. Tunde-Akintunde, O. J. Oyelade and B. O. Akintunde, "Effect of drying temperatures and pre-treatments on drying characteristics, energy consumption, and quality of bell pepper," *Agricultural Engineering International: CIGR Journal*, vol. 16, no. 2, 2014, pp. 108-118.

[27] A. O. Raji and S. A. Oke, "Optimization of EDM for AA6061/10%Al2O3 AMMC using Taguchi schemes and analytical hierarchy process for weight determination," *Kufa Journal of Engineering*, vol. 11, no. 3, 2020, pp. 42-61.

[28] S. Nwafor, S. Oke and C. Ayanladun, "Taguchi optimisation of cast geometries for A356/organic particulate aluminium alloy composites using a two-phase casting process," *Journal of Applied Science & Process Engineering*, vol. 6, no. 2, 2019, pp. 386-411.

[29] A. D. Polyanin and A. V. Manzhirov, "Handbook of Mathematics for Engineers and Scientists," *Chapman & Hall/CRC, Boca raton, USA*, 2007.

Biographies

Oluwaseyi Ayodele Ajibade is a lecturer at the Department of Metallurgical and Materials Engineering, University of Lagos, Lagos, Nigeria. He holds a PhD in Metallurgical and Materials Engineering from the University of Lagos, Lagos. Nigeria. He is interested in composite materials.

Johnson Olumuyiwa Agunsoye is an Associate Professor at the Department of Metallurgical and Materials Engineering, University of Lagos, Lagos, Nigeria. He holds a PhD in Metallurgical and Materials Engineering from the University of Lagos, Lagos. Nigeria. He is interested in composite materials.

Sunday Ayoola OKE received his Ph.D. in Industrial Engineering from the University of Ibadan, Nigeria in 2008. He lectures at the Department of Mechanical Engineering, University of Lagos, Lagos, Nigeria. His research interest includes manufacturing and optimization studies.