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Modification of Gypsum Products (Part II): The Effect of Drying Methods on The Compressive Strength and Surface Hardness of Modified Gypsum Products

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ABSTRACT

Aims: Studying the effect of microwave drying on the physical and mechanical properties of modified Iraqi plaster and modified Plaster of Paris in comparison with open air drying method. **Materials and methods:** Two types of gypsum products were used in this study (Iraqi plaster, Plaster of Paris) with the combined additives (gum arabic 0.5%, calcium oxide 0.75%, and ferric oxide 0.2%) that incorporated within the two gypsum products. Physical and mechanical properties of the experimental gypsum products have been evaluated by measuring the compressive strength, surface hardness, and surface roughness. Mean, standard deviation, analysis of variance (ANOVA), and Duncan's multiple range statistical test were used to analyze the data. **Results:** ANOVA analysis showed that there was a significant difference in the compressive strength, surface hardness, and surface roughness between Iraqi plaster (I.P) and Plaster of Paris (P.O.P) with or without additives. **Conclusions:** At two hours time interval microwave oven drying, Iraqi plaster and Plaster of Paris samples were stronger than air dried samples; and microwave oven at 10 minutes for 800 Watt not only increased the strength of gypsum products samples, but also save time.

Keywords: Gypsum products, additives, microwave drying.

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INTRODUCTION

Dentists have often found that it is necessary to work with gypsum casts soon after separating them from the impressions, since wet cast usually has inadequate strength, and dentist normally must wait (24 to 48) hours before the cast is strong enough for manipulation[1,2]. Microwave drying technique has been shown to be an efficient and accurate method of drying many types of gypsum products with different programs[3,4].

However, there is little research on the use of microwave technique as a drying method for the gypsum products, and the ideal time and optimum power of microwave drying have not yet been determined. The aim of this study was to identify the effect of microwave drying on the compressive strength and surface hardness properties of modified Iraqi plaster and modified Plaster of Paris in comparison with open air drying method.

MATERIALS AND METHODS

The Materials used in this study were Iraqi Plaster (Al-Ahliya Co. for gypsum industries Ltd/ Baghdad), Plaster Of Paris (British gypsum Newark U.K 41593/106) with the combined additives (gum arabic 0.5%, calcium oxide 0.75%, and ferric oxide 0.2%)[5]. Total samples prepared for this study (235), Figure (1).

Microwave Drying Method of Gypsum Products: The microwave oven used in this study was (Panasonic NN-MX 36 WF, Japan). All samples (40 with and without additives) dried by this method were placed in the microwave oven after two hours from the start point of mixing.

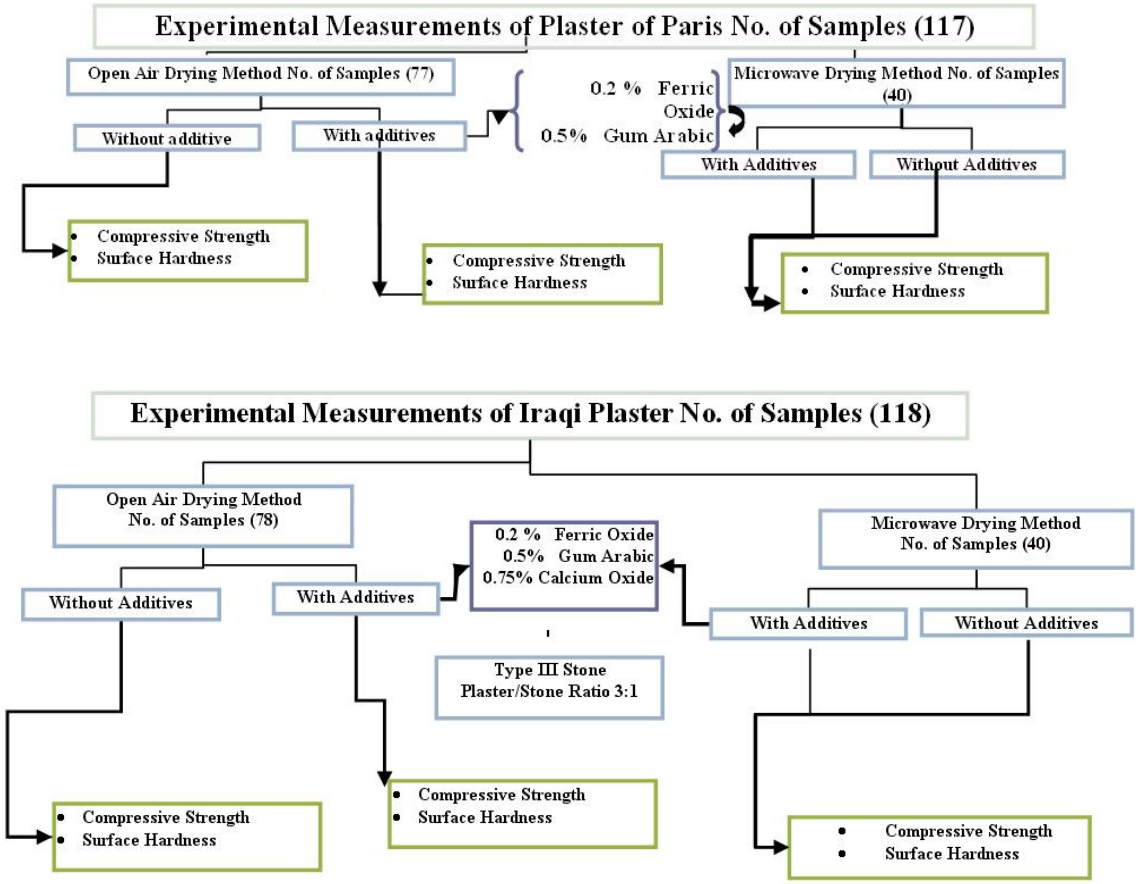

Figure (1): Flow chart for Plaster of Paris and Iraqi Plaster analysis.

The drying cycle was selected (high power level 1 of 100 % output of 800 watts for 10 minutes); this allowed the dried gypsum samples to be tested immediately after drying. A beaker with 400 ml of distilled water was placed in the microwave oven as a heat sink when all samples were micro- waved to protect the magnetron of the microwave oven when all the water has been removed from the gypsum samples[6]. The prepared samples were tested as follows:

Compressive Strength Measurement of gypsum products: The compressive strength values were determined according to ADA specifications No. 25 (1975)[7]. A special split moulds[8] were used to prepare 5 cylindrical specimens 20 mm in diameter and 40 mm. in height. Each sample was crushed after two hours from the start point of mixing by using (unconfined compression machine) at a loading rate of 980 ± 200 N/min (100 ± 20 Kg/ min) for plaster and 2900 ± 490 N/min (300± 50 Kg/ min) for dental stone. The compressive strength was determined from the value of the maximum load at the point of specimen fracture according to the following formula[9]:

Compressive Strength = Load (Kg) / Area (Cm2)*

*Surface area= Area of the circle = 3.14 Cm2

Surface Hardness Measurement of Gypsum Products: The measurement of the surface hardness was carried out according to (Luebke and Chan)[1].

The surface hardness measured at (24) hours time interval for open air and (2) hours for microwave oven drying from the start point of mixing.

Two cylindrical samples (10)mm. high and (20)mm. in diameter were produced at a time from each mould. The surface hardness was determined using a "microhardness tester".

Rockwell hardness test was used with minor load of (10) kg. and major load of

(50) kg[10,11]. A steel ball (1/2 inch) in diameter was used; a dial gauge on the tester was used to calibrate the depth of penetration on the flat surface of the prepared sample. In the minimum load, the dial gauge is set at zero point, and then the load gradually increased until it reached to the maximum load. The depth of indentation was measured by the dial gauge after the major load is again reduced to the minor load. Statistical analyses were done by ANOVA test.

RESULTS AND DISCUSSION

The compressive strength of both dental plaster and dental stone increased by time during the tested period is related to multiple factors: First, during the early stages, the gypsum product sample contains a lot of uncombined water which is caused by workability. Second, the progressive crystal growth and, accordingly, the interlocking of the resulted crystals increased by time. So by the use of a microwave oven as a drying method for the Iraqi plaster and Plaster of Paris with or without additives, Tables (1-6), and Figure (2), showed that the microwave drying method significantly increased the compressive strength of both compared with the compressive strength of these gypsum materials when dried in open air at two hours time interval. Good results are obtained when gypsum products tested with a mixture of additives(gum Arabic 0.5%, calcium oxide 0.75%, and ferric oxide 0.2%)[12]. An increase in the compressive strength by using the microwave drying technique could be explained by the presence of free water (excess water other than water required for the chemical reaction to convert the calcium sulfate hemihydrate to calcium sulfate dihydrate) in the gypsum sample resulting in weakening the structure. During microwave drying process as a result of heat production within the gypsum samples, excess water begins to evaporate, fine crystals of gypsum precipitate after the last traces of water disappear[6]. The heat production may also improve the crystal form of gypsum product which results in the increase of its compressive strength. The high power level (800 Watt) with ten minutes used in this drying cycle allows sufficient excess water to be evaporated from the plaster sample which has already a higher water/ powder ratio, resulting in an improvement of the compressive strength; this agrees with Al- Hadad et al[3]. On the other hand, using the microwave oven for drying dental stone with a high power level is not recommended especially for extremely wet casts because of rapid water escape from the dental stone which may be harmful to the material causing holes and cracks on the outer surface and lead to fracture during handling[2,3].

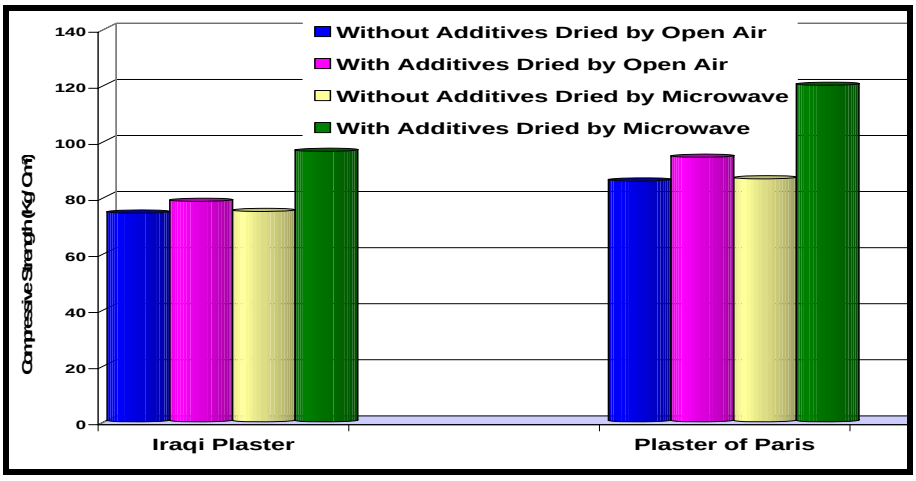

Figure (2): Means of the compressive strength gypsum products with and without additives dried by open air and microwave oven.

Table (1): Mean, standard deviation, and Duncan's multiple range test of the compressive strength, surface hardness for the gypsum products, without additives (air drying).

Types of gypsum products	Compressive strength (Kg/cm²)			Surface hardness(N/cm³)		
	Mean ± SD	Duncan's Group	N	Mean ± SD	Duncan's Group	N
Iraqi plaster	74.470 ± 1.3312	B	5	20.00 ± 0.7071	B	5
Plaster of Paris	85.924 ± 0.7439	A	5	24.60 ± 2.3022	A	5

SD: standard deviation; N: Number of sample, Means with different letters vertically are statistically significant.

Table (2): Analysis of variance (ANOVA) of compressive strength, and surface hardness of gypsum products without additives (air drying).

Test	Sum of Squares	df	Mean Square	*F*-value	*P*-value
Compressive strength(Kg/cm²)	87848.179	3	29282.726	2741.165	0.001*
Surface hardness	38189.000	3	12729	1552.398	0.001*

* Significant difference; df: Degree of freedom.

Table (3): Mean and standard deviation of the compressive strength , surface hardness for the two gypsum products with additives (Air drying, and Microwave techniques).

Types of gypsum products	Compressive Strength (Kg/cm²) Mean ± SD And Sample Number				Surface hardness (N/cm³) Mean ± SD And Sample Number			
	Air Drying	N	Microwave Drying	N	Air Drying	N	Microwave Drying	N
Iraqi plaster	78.657 ± 2.3138	5	96.50 ± 6.5075	5	22.600 ± 1.1402	5	27.400 ± 1.5166	5
Plaster of Paris	94.392 ± 1.5940	5	120.064 ± 5.807	5	33.800 ± 0.9623	5	59.400 ± 7.0214	5

SD: standard deviation; N: number of sample.

Table (4): Independent sample t-test for quality of mean of the two gypsum products with additives, air drying for the compressive strength, and surface hardness tests.

Test	T	df	SE	*P*-value	T
Compressive strength(Kg/cm²)	- 12.522	8	1.2565	0.001*	- 12.522
Surface hardness	-6.074	8	1.8439	0.001*	-6.074

* Significant difference; df: degree of freedom; SE: standard error

Table (5): Mean and standard deviation of the compressive strength , and Surface Hardness of the two gypsum products without additives(microwave drying).

Types of gypsum products	Compressive strength (Kg/cm²)		Surface Hardness (N/cm3)	
	Mean ± SD	N	Mean ± SD	N
Iraqi plaster	75.0422 ± 2.7055	5	22.200 ± 0.8367	5
Plaster of Paris	86.6912 ± 1.6290	5	48.000 ± 2.6689	5

SD: standard deviation; N: number of sample.

Table (6): Independent sample t-test for quality of mean of the two gypsum products without and with additives dried by microwave for the compressive strength.

Compressive strength	T	df	SE	*P*-value
without additives	-8.248	8	1.4123	0.001*
with additives	-6.039	8	3.9007	0.001*

* Significant difference; df= degree of freedom; SE= standard error.

By the use of a microwave oven as a drying method, Table (7), and Figure (3), there is a significant increase in the surface hardness for both the Iraqi plaster and Plaster of Paris (with or without additives). It is not surprising that dental plaster is the most affected by the microwave oven-drying method, but this method is not recommended for the extremely wet cast or using a high power level for drying the dental stone casts. Since the rapid removal of water from the wet gypsum sample (soon after separated from the impression) by microwave oven drying does not allow the fine crystals of gypsum precipitate to anchor the large crystals of the dihydrate formation[1,13].

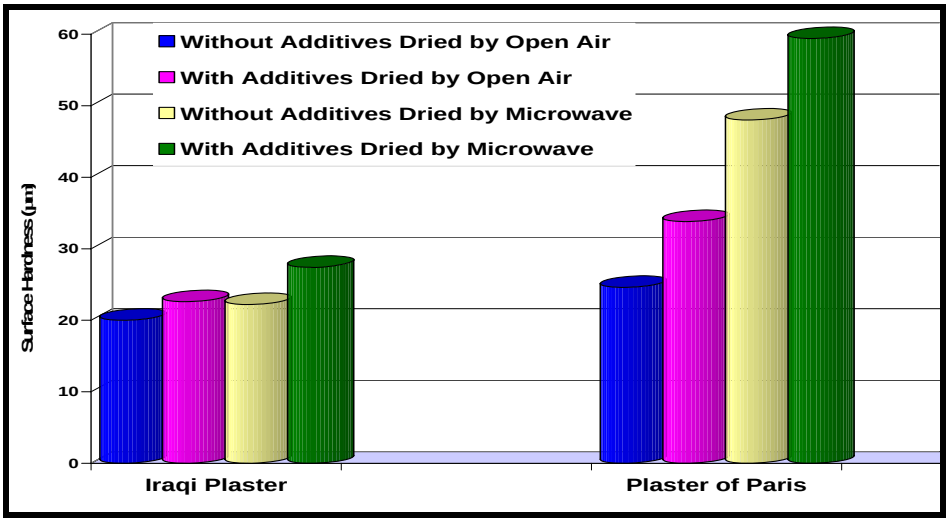

Figure (3): Means of the surface hardness for gypsum products with and without additives dried by open air and microwave oven.

Table (7): Independent sample t-test for quality of mean of the two gypsum products without and with additives for the surface hardness dried by microwave.

Surface Hardness	T	df	SE	*P*-value
Without additives	-4.544	8	5.6780	0.001*
With additives	-9.961	8	3.2125	0.001*

* Significant difference; df= degree of freedom; SE= standard error.

CONCLUSIONS

At two hours time interval microwave oven drying, the Iraqi plaster and Plaster of Paris samples are stronger than air dried samples; and good results are obtained when gypsum products tested with a mixture of additives. Microwave oven at 10 minutes for 800 Watt not only increases the strength of gypsum products samples, but also time saving.

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