EXPERIMENTING WITH REFRIGERATED MARGARINE AS PHASE CHANGE MATERIAL AND ZEOLITE AS DESICCANT FOR TEMPERATURE AND HUMIDITY CONTROL IN PHILIPPINE ARCHIVES

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Abstract

Incorrect levels of temperature and relative humidity hasten the deterioration of paper-based archives, irrespective of geographical location. An attempt to find a cheaper alternative to the costly installation of heating, ventilation, and air conditioning systems, the current research sought to test the capacity of different amounts of refrigerated margarine and zeolite respectively as alternative temperature and humidity control agents in archives in the Philippines, where varying amounts of sunlight and humidity during different times of the year become detrimental to maintaining an ideal storage condition. The resulting storage temperature and relative humidity where the test materials were introduced were compared against the temperature and relative humidity in storage where other commercially available phase change material (PCM) and desiccant were introduced, the room temperature and relative humidity, and the international standard temperature and relative humidity for archival storage. It had been found out that the optimum amount of refrigerated margarine that could perform well in the archive was 120 g as it resulted to an average temperature of 29.9475 ˚C, which was the closest any of the PCM samples used could get to achieve the standard archival temperature of 20 ˚C. On the other hand, the optimum amount for zeolite was 60 g. It resulted to an average of 57.825% relative humidity, which was 17.825% higher than the required relative humidity for archives. The best outcomes were observed when the two materials were introduced independently to the storage. Despite being able to deliver the desired results, refrigerated margarine and zeolite still require a few improvements before they become ready for their intended applications in archives. The small optimum amount of the refrigerated margarine and zeolite are beneficial in that it entails lower cost of materials.

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Introduction

Paper Preservation

The archive holds documents and records that contain information of enduring value. The focus of this study is on archival materials that come in the form of paper that are either yellowing, brittle, once mold-infested, tattered, or a combination of these.

In the ideal case, any given archival institution would address damages regardless of type and severity. Nevertheless, it needs to be kept in mind that the preservation of the physical state of archival materials is only a means to an end. It may be done in more ways than one for it is the information contained in each page that the archives are attempting to pass on to the generation of users to come.

Archives can deteriorate naturally like most material things. As for those made of paper, the culprits are usually the chemicals used during production. The acids that are applied to make ordinary paper are not totally wiped out. Hence, what is left on the product can continue to break down its cellulose fibers. They can do so even more rapidly when papers are stored under inappropriate environmental conditions.

Environmental factors such as temperature and relative humidity, although inherently harmless, can reach unideal levels and eventually cause unwanted changes in the physical makeup of paper. Drying and embrittlement are caused by a combination of low relative humidity and high temperature while swelling, warping, blotting, and mold growth are brought about by high relative humidity (International Records Management Trust & International Council on Archives, 1999).

Environmental Control in Philippine Archives

The internationally recognized standard temperature and relative humidity for archival storage, according to International Records Management Trust (IRMT), are 18-20 ^{0}C and 35-40%, relatively and irrelevant of where the materials are stored in the world. These temperature and relative humidity levels are hardly attainable for tropical countries like the Philippines, where the temperature plays between 25 ^{0}C and 32 ^{0}C and the relative humidity is around 77% (World Weather & Climate Information, 2015).

The difference of around 10 ^{0}C in temperature and around 40% in relative humidity can easily be closed through the installation of a heating, ventilation, and air conditioning (HVAC) system. However, most local archives opt not to avail of this necessity and for a considerable reason. The problem does not end once an HVAC system is acquired for there is still a need for proper maintenance and sometimes the latter costs even more.

The proper way is to keep the HVAC system running round the clock. When a scarcely funded institution has to turn it on only during operating hours, thinking that doing so would be good on their savings, it would just risk the physical state of their collections. Archives are actually better off in a workable substandard but stable environment than in one which only maintains ideal conditions for certain hours during the day.

As a means to better temperature and relative humidity conditions in Philippine archives and elsewhere applicable, a couple of passive and non-invasive alternatives had been explored in this study—the use of refrigerated margarine and zeolite as phase change material and desiccant, respectively.

Refrigerated Margarine as PCM and Zeolite as Desiccant

Refrigerated margarine is a soft variety of table margarine—those which are commonly used in households. It can completely melt in room temperature at around 35 ^{0}C (Miskandar, Man, Yusoff, & Rahman, 2005), so it was preferred to be used as a phase change material (PCM) in the present study. A PCM can be any material that, at constant temperature, is capable of absorbing and releasing relatively high amounts of energy through phase changes such as solidifying and liquefying.

Zeolite, on the other hand, was intended to act as desiccant. Its uniformly sized pores and large surface area make it ideal for attracting or repelling molecules of varying sizes and polarity. This is beneficial for the present study because this assures that the reactions only take place on the surface, resulting to almost no loss and/or change in the material's structure after each application.

The use of the two materials was envisioned to aid in the improvement of environmental conditions specifically in archives having inadequate or no HVAC systems. Through this effort of creating a sustainable preservation environment, it is made possible for a greater number of future users to access the information that come with each part of the archival collection.

The effectivity of using refrigerated margarine as phase change material and zeolite as desiccant were measured through their respective abilities to reduce temperature to 20 ^{0}C and relative humidity to 40%. The data obtained from setups where the test materials were introduced were compared with those obtained from setups kept at normal archival storage conditions and from separate setups introduced with commercially available PCM and desiccant.

Since the study was exploratory in nature, the experiment was carried out in the micro level, simulating the actual archival storage conditions. For safety reasons, deselected books were used in creating the setups. The PCMs and desiccants were enclosed in packaging materials which were deemed appropriate—two layers of resealable polyethylene bags for the refrigerated margarine and urea-water solution, aluminum containers for the oven-dried zeolite, and the original packaging material for the silica gel.

Conceptual Framework of the Study

It had been theorized that a higher amount of refrigerated margarine would result to lower temperature in a setup where it was introduced, whereas a higher amount of zeolite would render a higher amount of moisture adsorbed. The attainment of optimal results could be hindered by factors such as the size of the exposed surface area for the desiccants and the type of packaging materials used for both PCMs and desiccants. The weather plays a significant role as well for, as an example, a few minutes of rain could cause the temperature to drop and the relative humidity to rise radically.

Methodology

Procedure

The venues for the execution of the experiment were carefully chosen so as to render similar, if not the same, environmental condition as that of an actual archive located in a tropical country like the Philippines. The setups were organized as required in one of the storage rooms in the same building as the University of the Philippines University Archives and Records Depository and later on transferred to a vacant room in a nearby residential area. It was made sure that all materials involved were able to adapt to both storage environments for three days before measurements were derived. The filing storage boxes were filled with the deselected books and organized one foot apart.

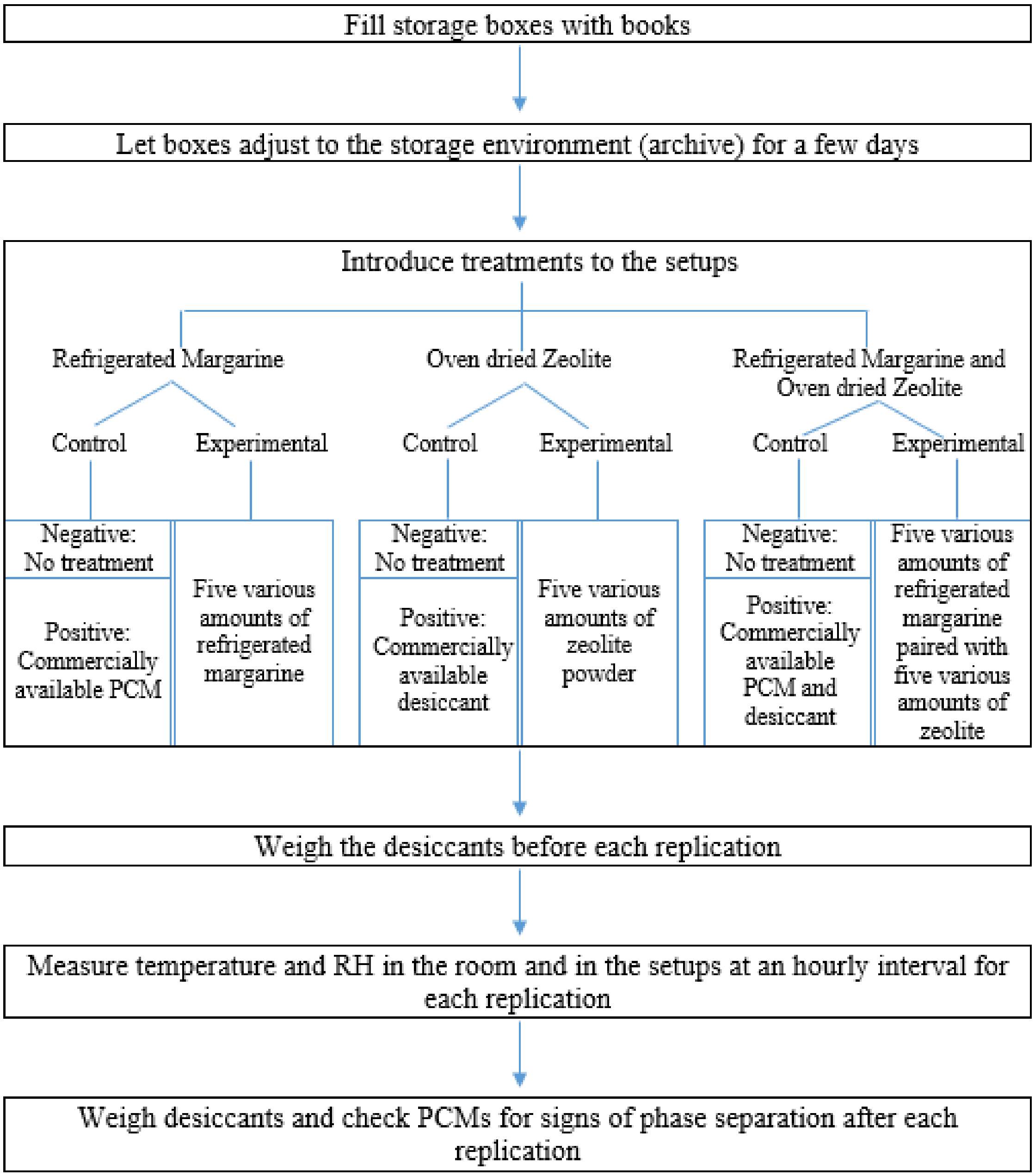

Figure 1. Schematic diagram of the experiment.

Two sets of different amounts of the phase change materials were packed using two layers of 4 × 6 in. polyethylene bags—30 g, 60 g, 90 g, 120 g, and 150 g of refrigerated margarine for the experimental setups and 50 g of urea dissolved in 50 mL of water for the positive control setups.

Two sets of 20 g, 40 g, 60 g, 80 g, and 100 g zeolite samples were dried for one hour at 105±1 ˚C in a convection oven to remove previously accumulated moisture. They were allowed to cool down in desiccators and placed inside zip lock containers as soon as they reached room temperature to prevent further adsorption of moisture. For the corresponding positive control, two 100 g silica gel packets were prepared.

The negative control setup was not provided with any of the test materials.

Table 1

Amounts of PCM and Desiccant that were Introduced to the Setups

Setup	Amount of Refrigerated Margarine in grams	Amount of Zeolite powder in grams
C_0	0	0
C_1	100 g urea dissolved in water (1:1)	
C_2	100 g silica gel	
C_3	100 g urea dissolved in water (1:1), 100 g silica gel	
M_1	30	0
M_2	60	0
M_3	90	0
M_4	120	0
M_5	150	0
Z_1	0	20
Z_2	0	40
Z_3	0	60
Z_4	0	80
Z_5	0	100
MZ_1	30	20
MZ_2	60	40
MZ_3	90	60
MZ_4	120	80
MZ_5	150	100

All phase change materials were mixed gently at the beginning of each experiment day and checked for signs of phase change or separation at the end. The desiccants, on the other hand, were weighed before and after each experiment day. These were sealed in their respective plastic containers whenever not in use.

Measurements were made at one-hour intervals from 9 a.m. to 4 p.m. One thermo-hygrometer was utilized to measure the room temperature and relative humidity from a stationary position while another one was used to measure the temperature and relative humidity inside the storage boxes used in each setup.

Analysis of Data

Five replicates were done per setup and three sets of data were gathered. The first set was intended to optimize the amount of refrigerated margarine when used on its own, the second to optimize the amount of zeolite when used on its own, and the third to optimize the amounts of refrigerated margarine and zeolite when used together.

The mean hourly temperature and relative humidity measurements for all setups were arranged in a scatter plot to create a simplified representation of the data obtained from the experiment.

Since the measurements were independent of each other, the total mean differences between the setup temperature and RH and the standard, room, positive control, and negative control temperature and RH were first calculated. Using Microsoft Excel, single factor Analysis of Variance (ANOVA) was then applied on the values obtained. ANOVA was used to prove whether or not there was a significant dissimilarity between the differences recorded.

The same differences in temperature and RH were compared again and either the minimum or the maximum value was determined, depending on the criterion being discussed. For instance, the minimum total mean difference between the setup and the standard temperature and RH was preferred while the maximum total mean difference between the setup and the room temperature and RH was sought after.

Results

Refrigerated Margarine

All phase change materials used during the experiment showed signs of phase separation of various intensities. Setup M_4 with 120 g refrigerated margarine exhibited the most favorable temperature results. It garnered the closest temperature, 29.9475 ˚C, to the standard condition. This, on the average, turned out to be 0.55 ˚C lower the room temperature, 0.15 ˚C lower than the negative control temperature, and 0.07 ˚C lower than the positive control temperature.

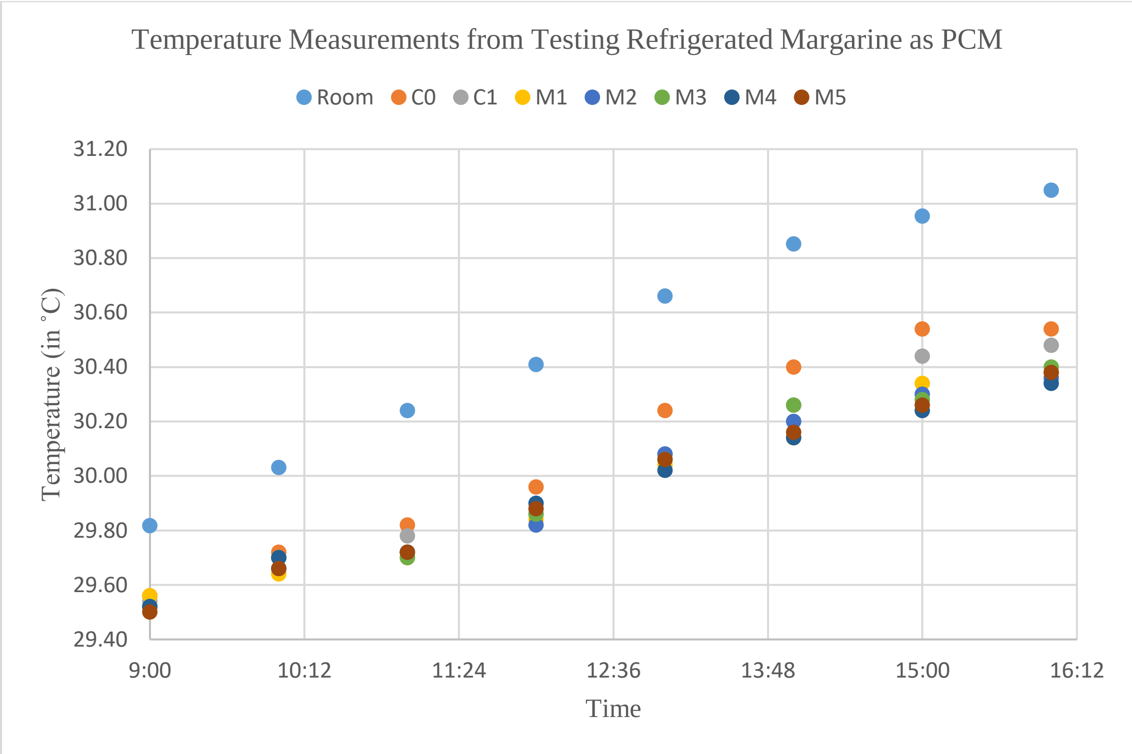

Figure 2. Graph of the mean temperature measurements from testing refrigerated margarine as PCM.

<u>Zeolite</u>

None of the zeolite samples performed better than the silica gel sample. The most probable cause considered for this was the difference in their packaging materials and the exposed surface area of the test materials. The silica gel was not taken out of its original container that was made of highly absorbent material, while the zeolites were contained in aluminum canisters, which were only open at the top. Results showed that the positive control RH was only 16% above the standard RH. It was also 2.3321% lower than the room RH and 4.575% lower than the negative control RH.

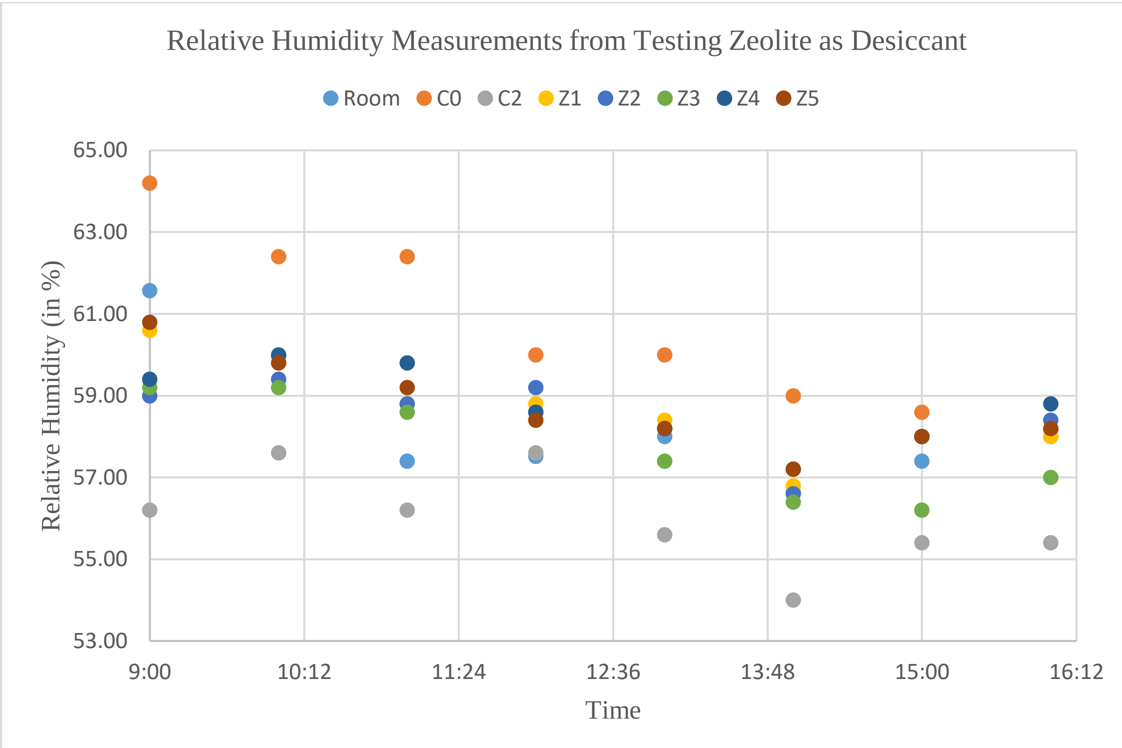

Figure 3. Graph of the mean relative humidity measurements from testing zeolite as desiccant.

Setup Z_3 with 60 g of zeolite showed the best performance among zeolite samples tested. It provided a mean relative humidity that was 17.825% higher than the standard RH, 0.5071% lower than the room RH, 2.75% lower than the negative control RH, and 1.825% higher than the positive control RH. Z_3 was one of the samples which adsorbed the highest amount of moisture (3 g) next to the positive control (18 g).

Refrigerated Margarine and Zeolite

All the margarine samples also displayed phase separation when the samples were used along with the desiccants in the last phase of the study. Setup MZ_2 with 60 g of refrigerated margarine and 40 g of zeolite ended up being the best candidate in terms of reducing the temperature. Its mean temperature was 31.095 ˚C, which was 11.095 ˚C higher than the standard temperature. It was 0.48 ˚C lower than the room temperature, 0.005 ˚C lower than the negative control temperature, and 0.2175 ˚C lower than the positive control temperature.

Comparing the RH data, setup MZ_1 with 30 g of refrigerated margarine and 20 g of zeolite proved to be the second best to the positive control setup C3. The positive control RH was 15.525% higher than the standard RH, 2.8107% lower than the room RH, and 5.05% lower than the positive control RH. MZ_1's RH was 18.5% higher than the standard RH, 0.1643% higher than the room RH, 2.075% lower than the negative control RH, and 2.975% higher than the positive control RH. Ironically, MZ_1 only adsorbed 1 g of moisture white MZ_2 got 4 g. Meanwhile the control setup C_3 accumulated 13 g.

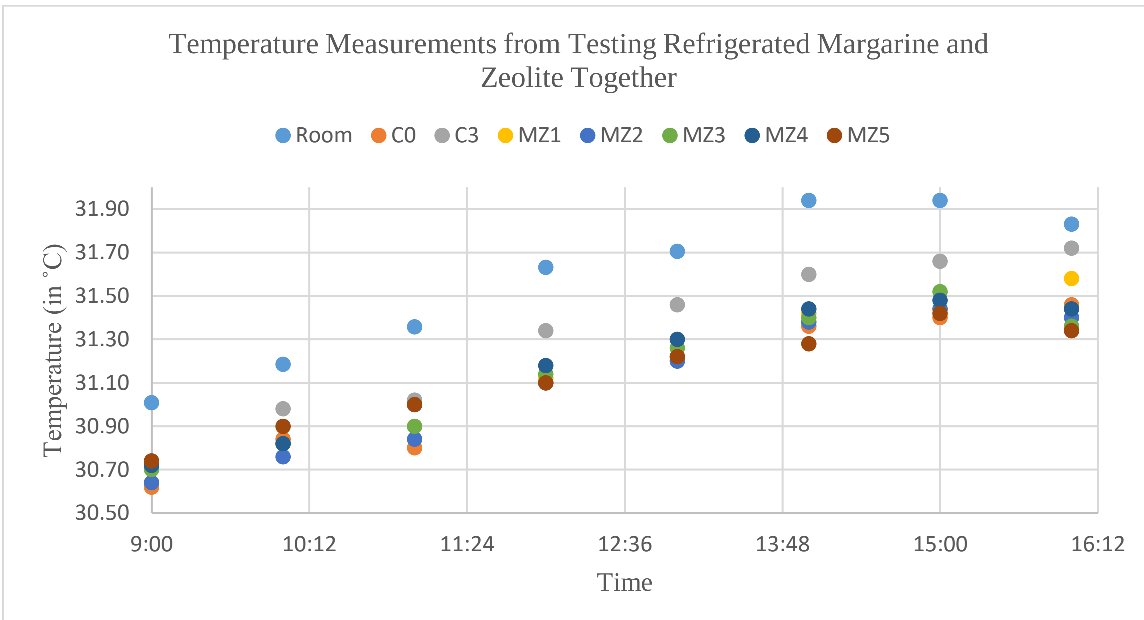

Figure 4. Graph of the mean temperature measurements from testing refrigerated margarine and zeolite together.

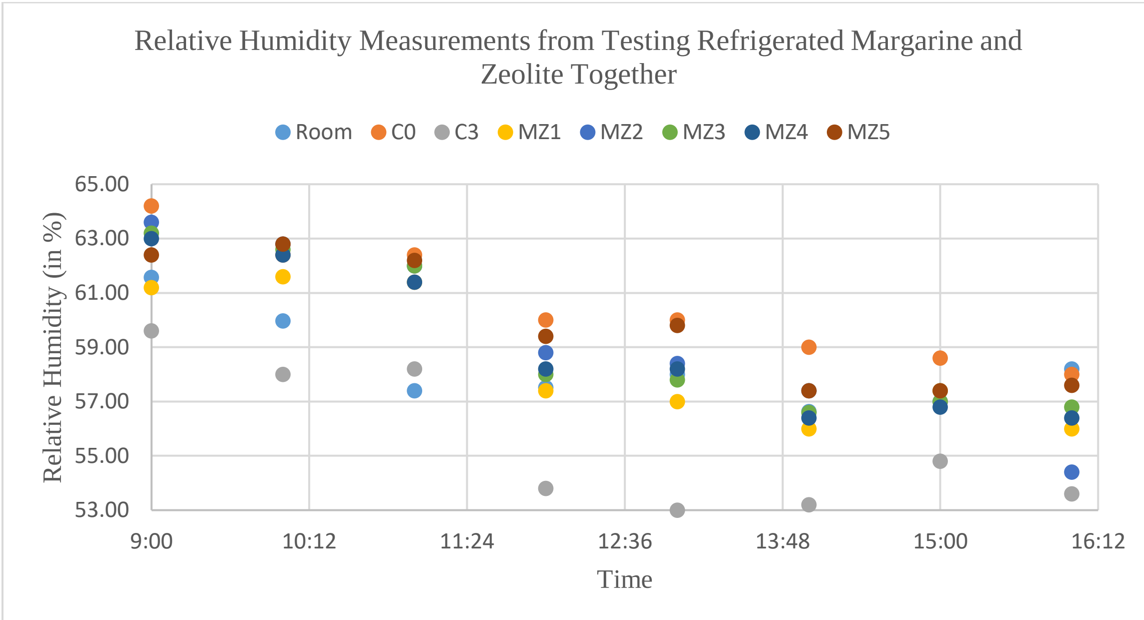

Figure 5. Graph of the mean relative humidity neasurements from testing refrigerated margarine and zeolite together.

Different experimental setups performed satisfactorily in terms of temperature and RH. Both cannot simply be chosen as the best since their performances were not very close. MZ_2, the best in reducing the temperature, did not do very well in reducing the amount of moisture, while setup MZ_1, the best in reducing the RH, was not one of the best in lowering the storage temperature.

Conclusion and Recommendation

The optimum amount of refrigerated margarine was 120 g. It resulted to an average temperature of 29.9475 ˚C, which was the closest any of the PCMs could get to the standard temperature, 20 ˚C. It was also lower than the room temperature by 0.55 ˚C, the negative control by 0.15 ˚C, and the positive control temperature by 0.07 ˚C. Furthermore, it exhibited phase separation in the form of oil melting away from the mixture.

The performance of the zeolite samples was not as good as that of the silica gel samples. The optimum amount for zeolite that was 60 g achieved an average of 57.825% relative humidity, which was 0.5% higher than the room RH, 2.75% lower than the negative control RH, and 1.825% higher than the positive control RH. It was able to adsorb a total of 3 g of moisture throughout the five replications.

Both refrigerated margarine and zeolite best exhibited the desired outcomes when they were used independently. However, despite having achieved promising results and having observed no adverse effects on the books and storage boxes used, the downside is that the test materials are not yet ready for their intended application in archives.

It is suggested that further studies are executed particularly on the development of more viable packaging materials that will promote better latent heat absorption for the refrigerated margarine and more efficient moisture adsorption for zeolite. The use of similar products or variations of the test materials and the utilization of more advanced temperature and relative humidity measuring tools that could execute continuous or automated data collection are also highly recommended.

The small optimum amounts of refrigerated margarine and zeolite are advantageous for archival institutions as these entails lower cost of materials. Particularly for scarcely funded Philippine archives, the availability in the local market of these sustainable materials and others that can also be used as environment control agents opens numerous opportunities to try out alternative methods for creating ideal archival storage settings.

When used to their maximum potential, these materials are expected to help in cutting down the expenses on employing high maintenance HVAC systems without compromising the primary goal of protecting paper archives from damages caused by improper levels of temperature and relative humidity.

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