# Effects of Drying and Salt Extraction of *Moringa Oleifera* on Its Coagulation of High Turbidity Water

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**Abstract:** *Moringa oleifera* (M.O.) has been used as a natural coagulant in water treatment. The present study aims to determine the effect of drying M.O. seed powder that has been extracted with salt ($NaNO_3$) on the coagulation of synthetic (kaolin) water of 200±5 NTU. The optimum quantity of M.O. was 5 mg for both 10 and 200 g/l concentrations of the non-spray-dried salt-extracted M.O. (MOC-SC) solutions, with turbidity removal of 87%. This maximum turbidity removal was achieved with 1 M and 0.5 M of $NaNO_3$ salt in the former and latter concentrations, respectively. The spray-dried M.O. (MOC-SC-SD) solutions exhibited better maximum turbidity removal of more than 95%, which also occurred at 5 mg of M.O., for both concentrations. Finally, the duration of storage of MOC-SC-SD did not affect its performance in the removal of turbidity. [Journal of American Science 2010;6(10):387-392]. (ISSN: 1545-1003).

**Keywords:** Coagulation; *Moringa oleifera*; spray drying; turbidity removal; water treatment

## 1. Introduction

A coagulant is one of the key components for removing turbidity in a water treatment process (Warhurst et al., 1996; Katayon et al., 2006). Chemical salts such as aluminum and iron are most widely used in the coagulation process (Okuda et al., 1999). Also there are problems of low efficiency coagulation in cold water and reduction of alum with natural alkalinity presence in water which lead to a reduction of pH (Haarhoff and Cleasby, 1988). The high cost of imported chemicals such as alum is also considered as a burden to the economy of a developing country (Schulz and Okun, 1983).

Recently, researchers have shown an increased interest in using healthy products as natural coagulants (Schulz and Okun, 1983; Lee et al., 1995). Among these, *Moringa oleifera* (M.O.) seeds are quite commonly used as a primary coagulant for water treatment (Muyibi et al., 2002a, b). Many studies have been carried out to assess the performance of *Moringa oleifera* coagulant extracted with distilled water (MOC-DW) for removing turbidity. The mechanism of suspended solids removal by the coagulation active component in M.O. has been described (Ndabigengesere and Narasiah, 1998). Salt water has also been used to extract the active coagulation component from M.O. seeds and compared with the conventional method of extraction using distilled water (Okuda et al., 2001). Prasad (2009) found no differences in the coagulation efficiency for M.O. extracts using each of the solutions of NaCl, $KNO_3$, KCl, $NH_4Cl$ and $NaNO_3$ with distilled water.

In the coagulation process turbidity has been categorised into four, namely; low turbidity (smaller than 50 NTU), medium turbidity (50 – 100 NTU), high turbidity (100–200 NTU), and very high turbidity (greater than 300 NTU). A study showed that M.O. might not be an effective coagulant for low and medium turbid water, whereby only 50% turbidity removal was achieved with low turbidity water sample (23 - 90 NTU) (Katayon et al., 2006).

The effects of salt-extracted M.O. to remove an anionic surfactant have also been investigated. The improvement in extraction efficiency by salt was ascribed to the salting-in mechanism, which increased the ionic strength and solubility of the active components (Ndabigengesere and Narasiah, 1998). The M.O. coagulant extracted with salt (MOC-SC) differs in the molecular weight of the active component from that of the MOC-DW (Gassenschmidt et al., 1991; 1995).

Spray-drying is one of the techniques available for micro-encapsulation process, in which tiny particles or droplets are surrounded by a coating that can enhance the absorption or extraction process (Jafari et al., 2008). Several studies investigating encapsulation have been carried out. Encapsulation by spray drying process was responsible for the increase in the lycopene extraction from 96.4 to 98.1% (Fuchs *et al.*, 2006; Nunes and Mercadante, 2007). Another study found that improvement in oil extraction in the supercritical fluid extraction method could be achieved by the encapsulation mechanism (Shih and Daigle, 2001). Drying is one of the most widely used processes to reduce the weight and increase the storage life of numerous products and materials. The spray drying method is widely used in food industry, and the food ingredients processed under optimal processing conditions have a high degree of solubility, good emulsifying properties, good drying properties, no hygroscopic character, bland taste, no reactivity, and low cost (Murúa-Pagola et al., 2009). In addition, the high temperature spray drying process is reported to have no effect on a product (Cano-Chauca et al., 2005).

Although numerous studies have been attempted to find the *Moringa oleifera's* efficiency as a coagulant, the effects of M.O. encapsulation by spray-drying process on its performance have not been established. Thus, the aim of the present study is to investigate the effect of spray drying on the performance of M.O. in coagulation, including the effect of storage duration.

## 2. Material and Methods

### 2.1 Preparation of *Moringa oleifera* seeds powder

The M.O. seeds were obtained from locations within the Universiti Putra Malaysia. High quality seeds, those which were new and not infected with disease, were selected. Seeds were opened and then dried in an oven (Memmert, ULE 400, Germany) for 24 hr at 50°C. A rice husk-removing machine (Satake, THU class) was used to remove the hulls and wings from the kernels. The kernels were crushed and ground to a medium fine powder with a domestic food blender (National De-Luxe Kitchen Family, Japan). The process of preparing the M.O. seed powder is shown in Figure 1.

### 2.2 Preparation of *Moringa oleifera* solution

The MOC-SC was prepared following the procedure used by {(Okuda et al., 1999). In the present study, M.O. solutions of 10 g/l and 200 g/l concentrations were used. Appropriate quantities of M.O. seeds powder were placed in six beakers that contained 500 ml of distilled water each. For each concentration, 1.5 M, 1 M or 0.5 M of $NaNO_3$ salt was added. All mixtures were blended for 1 min using a domestic food blender at high speed to extract the active ingredient of M.O. The suspension was then filtered through a muslin cloth into a beaker to form the stock solution for each combination of concentration and molarities above. This filtrate is referred to as MOC-SC while the M.O. filtrate prepared in the same manner, but using distilled water only is referred to as MOC-DW.


Figure 1: Preparation of *Moringa oleifera* seeds powder

### 2.3 Preparation of turbid water

Synthetic turbid water was prepared by adding kaolin (R and M Marketing, Essex, UK) into distilled water to obtain the required turbidity. The suspension was stirred slowly at 120 rpm for 1 hr in a jar test apparatus for uniform dispersion of kaolin particles. The suspension was then allowed to stand for 24 h to allow for complete hydration of the kaolin. This kaolin suspension was used as the stock solution for the preparation of water samples in the coagulation tests. In this study, only water samples with high turbidity (200 NTU) were tested.

### 2.4 Spray drying process

A spray dryer (LabPlant SD-05, UK) was the device used in the spray drying process. A solution is fed into the dryer and it then converts the constituents into solids and vapour. The liquid input stream is sprayed through a nozzle into a hot vapour stream and vapourised. Solids form as moisture quickly leaves the droplets. The solid particles are collected in a cyclone. The 500 ml MOC-SC with concentrations of 10 g/l and 200 g/l were used in the spray drying process. Table 1 shows the conditions in which the spray drying process was performed.

The powder that resulted from spray drying, known as MOC-SC-SD, was collected and packed in a sealed container, covered with aluminium foil and stored in a refrigerator. The efficiency of the spray drying process, evaluated on the basis of its yield (percent of spray dried produced/initial content), was found to be between 40 and 66%. The amount of solid lost during the process depends on the percentage of solid that sticks to the wall to the amount of powder eliminated with the exhausted gas. For the preparation MOC-SC-SD solution, distilled water (DW) was added to the MOC-SC-SD based on the original molarities.

Table 1: Spray drying conditions

| Condition | Concentration (g/l) | Inlet Temp. °C | Sample amount (ml) | Outlet temp. °C | Pump rate (rpm) |
|---|---|---|---|---|---|
| **A** | 10 | 120 | 100 | 75 - 103 | 15 |
| **B** | 10 | 130 | 100 | 81 - 105 | 15 |
| **C** | 10 | 140 | 100 | 83 - 112 | 15 |
| **D** | 200 | 120 | 100 | 73 - 91 | 15 |
| **E** | 200 | 130 | 100 | 78 - 97 | 15 |
| **F** | 200 | 140 | 100 | 89 - 103 | 15 |

**2.5 Coagulation test**

A set of experimental runs were carried out to determine the optimum quantities of the MOC-DW, MOC-SC and MOC-SC-SD for coagulation of water samples. The coagulation tests were carried out using the jar test (BIBBY Stuart Scientific, UK). The tests involved rapid mixing, followed by slow mixing and sedimentation in a batch process. Six beakers were filled with 500 ml of the synthetic turbid water samples, and placed on the floc illuminator and agitated at the preselected speed of rapid mixing as shown in Table 2. During the rapid mixing, a known dosage of M.O. was added to each beaker simultaneously using 20 ml test tubes. After the rapid mixing, the preselected speed of slow mixing was quickly established and when this was completed the beakers were then carefully removed from the floc illuminator and left for the sedimentation phase. After settling, 20 ml of the sample was taken from the middle of each beaker for turbidity measurement. The dosage that gave the lowest turbidity was the optimum dosage for this particular water sample. Turbidity measurements were conducted using a turbidity meter (HACH, 2100AN). All tests were repeated twice. All the dosages were expressed in term of the mass of M.O. powder (mg) in order to compare the effect of the different concentrations (10 and 200 g/l).

Table 2: Operating variables used to run the jar test (Muyibi and Evison, 1995; Okuda *et al.*, 2001)

| Rapid mix speed (rpm) | Rapid mix duration (min) | Slow mix speed (rpm) | Slow mix duration (min) | Settling time (min) |
|---|---|---|---|---|
| 100 | 4 | 40 | 25 | 30 |

**2.6 Statistical analyses**

The Minitab statistical package (Version 14) was used for all statistical analyses of the experimental results. All statistical significance was evaluated at the level of 95%. One-way analysis of variance (ANOVA), with Tukey multiple range test was carried out to verify the significance of differences between the means.

**3. Results and Discussion**

**3.1 Optimum dosage of *Moringa oleifera***

The results of the coagulation tests using the M.O. extracted with distilled water (MOC-DW) are shown in Figure 2. It can be seen that the optimum turbidity removals of about 77% were achieved with 80 mg of M.O. for both 10 g/l and 200 g/l concentrations. In the case of the tests on MOC-SC, the results by the different molarities with the 10 g/l and 200 g/l concentrations are shown in Figures 3 and 4, respectively. For both concentrations, optimum turbidity removals of 87% were obtained, which occurred when 5 mg of M.O. was used. However, for the 10 g/l solution, the optimum removal occurred with 1 M of $NaNO_3$, whereas in the case of 200 g/l solution, the optimum removal occurred with 0.5 M of $NaNO_3$. The optimum turbidity removal in this study was significantly higher than those obtained by a previous study (Gassenschmidt et al., 1991) which reported that the maximum turbidity removal of around 70% was obtained with 0.25 M salt solution. This difference might be due to the difference in experimental conditions employed such as settling time, mixing velocity gradient or it might also be due to the usage of different species of M.O. (Jahn, 1988). It is obvious from these results that the efficiency of MOC-SC in terms of the amount of M.O. powder required to produce the optimum performance was 16 times better than that of MOC-DW, in addition to the higher turbidity removal of the former. The present findings seem to be consistent with other researchers that found improvement in coagulation mechanism by the increase in ionic strength with salt that in turn caused the increase in the solubility of the active components (Muyibi and Evison, 1995; 1996).

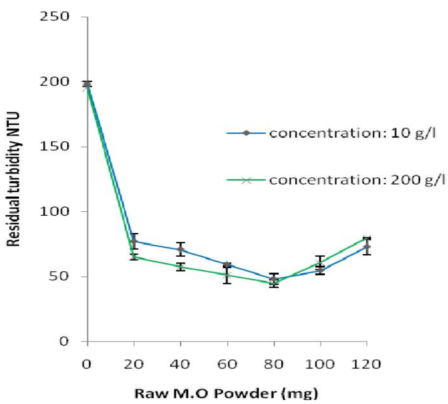


Figure 2: Average residual turbidity after coagulation with the MOC-DW solution of 10 g/l and 200 concentrations

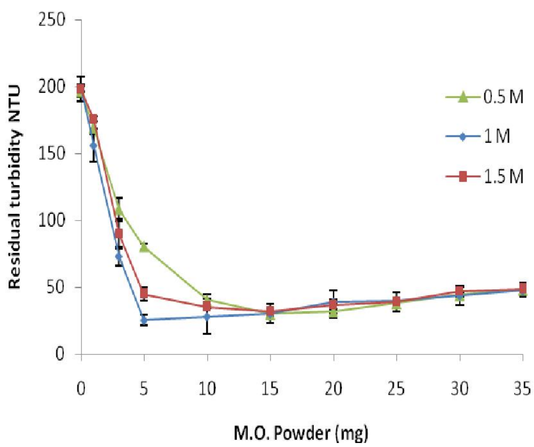


Figure 3: Average residual turbidity after coagulation with the MOC-SC solution of 10 g/l concentration

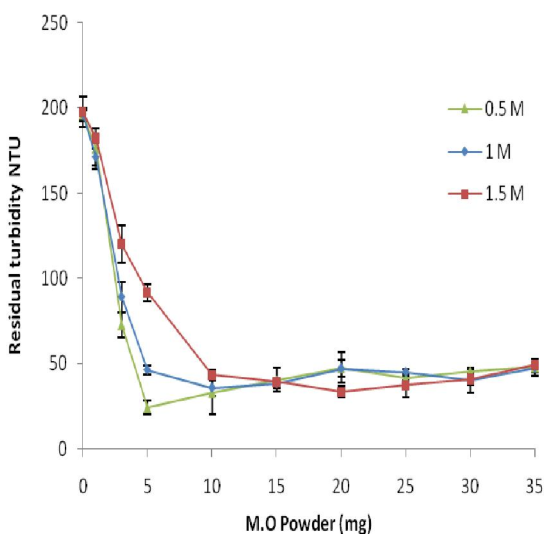


Figure 4: Average residual turbidity after coagulation with the MOC-SC solution of 200 g/l concentration

### 3.2 Effect of the drying process on the coagulation efficiency

Using the optimum molarities found above, coagulation tests were further conducted using the spray dried salt extracted M.O. (MOC-SC-SD) with 1 M and 0.5 M salts for the 10 g/l and 200 g/l solutions respectively. The optimum amounts of MOC-SC-SD with these concentrations are shown in Figure 5. The maximum removal was obtained with 5 mg of MOC-SC-SD in both concentrations tested. These optimum powders removed turbidity by more than 95% (conditions A and D). The coagulation tests for the spray dried powder obtained from each condition were done after the spray drying process. It was found that there were no significant differences ($P < 0.05$) in coagulation performance between each concentration for both optimum conditions (condition A: 10 g/l and D: 200 g/l).

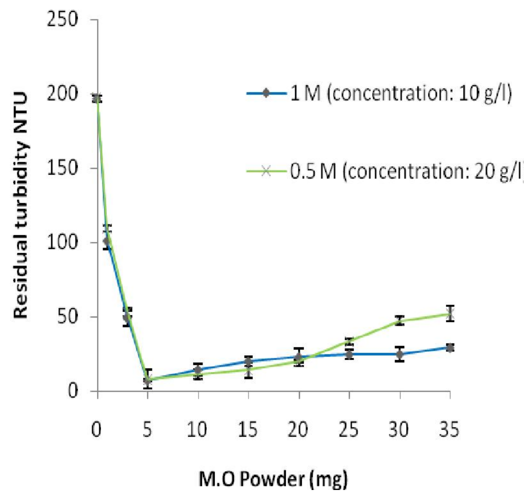


Figure 5: Average residual turbidity after coagulation with MOC-SC-SD solutions

### 3.3 Coagulation performance of non-spray-dried and spray-dried salt-extracted *Moringa oleifera*

Figure 6 presents the residual turbidity using MOC-SC and MOC-SC-SD after coagulation. The result shows that the optimum turbidity removal by 1 and 0.5 M MOC-SC in 10 and 200 g/l concentrations was 87% at 5 mg M.O. powder respectively. On the other hand, for the MOC-SC-SD 1 and 0.5 M salt extracted spray dried conditions A, D (10 and 200 g/l concentration) the removal turbidity was 96.4 and 95.3% at 5 mg M.O. powder. There was a significant difference in performance between MOC-SC-SD and MOC-SC turbidity removal. It is possible to relate these results to the encapsulation of M.O in powder by salt using spray drying. Coagulation activity of MOC also improved due to increased M.O extraction efficiency of spray drying process. This is in agreement with the findings of several published studies which discussed the effect of the spray drying process on active component extraction yield (Shih and Daigle, 2001; Fuchs et al., 2006; Nunes and Mercadante, 2007; Jafari et al., 2008).

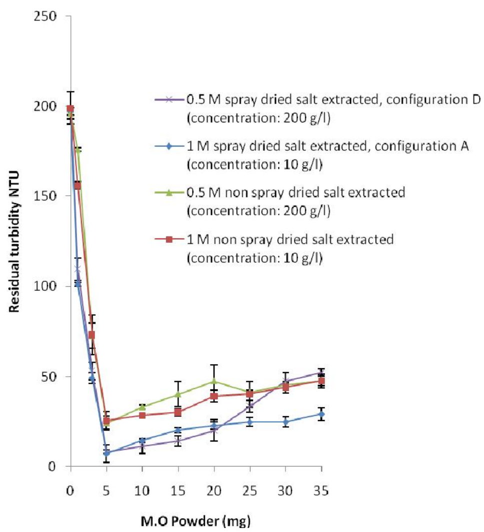


Figure 6: Coagulation performance of MOC-SC and MOC-SC-SD solutions

### 3.4 Effect of storage duration on coagulation efficiency

The M.O. spray dried powder of condition A was kept in a refrigerator at 3°C for 1, 2 and 3 weeks. Residual turbidity of coagulated water using M.O. stored for different durations was determined and the results are shown in Figure 7. It should be noted that the turbidity before coagulation for all durations was 200±5 NTU. These results showed that the coagulation performance did not decrease significantly at $P > 0.05$ with storage duration. This finding is in agreement with that reported by a previous study (Haarhoff and Cleasby, 1988). They also reported that there is no difference between the turbidity removal efficiency of M.O. kept in a refrigerator and in room temperature.

### 4. Conclusions

Coagulation performance of the salt extracted *Moringa oleifera* solution is not only affected by its concentration but also by the molarities of the salt used in the solution. The present study clearly shows that spray drying is an appropriate method to produce M.O. seeds that can be used to reduce turbidity in water treatment. Better coagulation performance and higher turbidity removal was achieved with a proper combination of M.O. solution concentration and salt molarities.

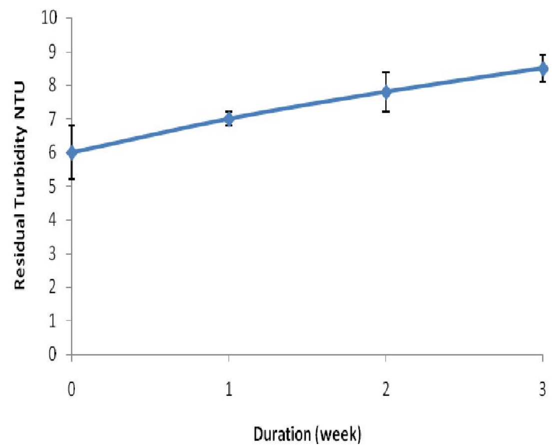


Figure 7: Effect of storage duration of M.O. powder on residual turbidity


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6/22/2010