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Contents:

(continued on outside back cover)

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Development and Characterization of Keratin Modified Urea Formaldehyde Resins

P. E. Dim, M. O. Edoga

Abstract – *The aim of this study was to develop and characterize keratin-modified-urea-formaldehyde resin. Firstly, poultry feathers were collected and then ground to 1.00 mm particle size. Subsequently, keratin was extracted from the poultry feather powder using an aqueous solution of sodium sulphide at 40°C for 3 hours. The extract was used in developing the urea-formaldehyde resin. The physicochemical properties of the resins which included viscosity, gel time, specific gravity, pH and total solid content of the modified resins were determined. These properties of the modified urea-formaldehyde resin were compared with those of neat urea-formaldehyde resins. The results showed that the modified urea-formaldehyde resins gave improved qualities than the neat urea- formaldehyde resin. The results of the physicochemical properties of the four resin samples namely the neat formaldehyde and three modified urea-formaldehyde resin samples are given as follows: viscosity, solid content, specific gravity, gel time; 260cp, 280cp, 300cp, 330cp; 62%, 63.5%, 66%, 69%; 1.45, 1.34, 1.29, 1.25; 180 s, 167 s, 120 s, 82 s, respectively.*

Keywords: *Keratin Modified Urea Formaldehyde Resins, Physico-Chemical Properties, Poultry Feathers*

I. Introduction

Recent attempts made by researchers and manufacturers alike in search of new direction for improving the qualities of urea-formaldehyde petrochemical, have yielded some positive result. The major types of adhesives in use are formaldehyde condensation polymers. These include urea-formaldehyde, phenol-formaldehyde, melamine-formaldehyde and resorcinol-formaldehyde petrochemicals. Among these petrochemicals derived adhesives, phenol-formaldehyde possesses the highest strength compared with the rest, but it is the most expensive. On the other hand, urea-formaldehyde resin which is the least expensive and most versatile petrochemical adhesive for wood bonding worldwide is susceptible to hydrolytic and thermal degradation [1]. The urea formaldehyde resin, though an excellent petrochemical based adhesive, has certain drawbacks. These drawbacks have drastically limited the applications of urea formaldehyde adhesive only to bonding wood products that will be used in interior non-structural areas. These disadvantages of urea-formaldehyde petrochemicals are singularly due to high susceptibility to thermal and hydrolytic degradation [2].

In the past, several efforts have been made by researchers to modify the structure of urea formaldehyde by incorporating some natural structure-modifying agents so as to improve on their thermal and hydrolytic properties.

Varieties of modifiers have been examined, and have been found to be beneficial for durability [1], [3]. These included red onion skin [3] etc. However, more attention is still required in augmenting the stability and hydrophobicity of cured urea-formaldehyde resin for bonding wood products. This work therefore, is focused on improving the stability and hydrophobicity of cured urea-formaldehyde resin. In view of the above target, any attempt to make the urea- formaldehyde resin hydrophobic will be a welcome development especially when the locally sourced materials used are a good source of structure modifier. Poultry feathers are approximately 91% protein (keratin), 1% lipid and 8% water [4]. Keratin is insoluble in water, weak acids and bases, as well as in organic solvents [5]. Keratin if properly incorporated into the urea-formaldehyde structure will make it hydrophobic rather than hydrophilic and can be used for bonding wood products meant for exterior structural engineering applications. Meanwhile, these efforts would result in new technique for improving the water repellency of urea-formaldehyde petrochemical adhesive which would subsequently broaden the markets for urea-formaldehyde materials as well as poultry feathers.

II. Materials and Method

Poultry feathers, detergent, ethylene alcohol, sodium sulphide, sodium hydroxide, cellulose sleeve, electric oven, urea, formaldehyde, acetic acid, jenway pH meter,

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brooksfield viscometer and techne gel timer, were used for experiments. The poultry feathers for the extraction of keratin were collected from various poultry farms. About 2 kg of poultry feathers was collected. The poultry feathers were washed 5 times with hot water and detergent. Subsequently, they were filtered and dried in the sun at atmospheric conditions for 2 days. Again, the poultry feathers were washed with ethylene alcohol and dried in the sun at atmospheric conditions for 3 days. After drying, they were ground to 1.00 mm to create a better surface area for contact with the solvent.

II.1. Extraction of Keratin

The ground feathers were dissolved in 0.7M aqueous solution of sodium sulphide. The experiment was conducted at a temperature of 40^{o}C for 3 hours. At the end of the process, the keratin in the solution was filtered to separate the insoluble parts of the feather from the soluble part. The extracted keratin was subjected to dialysis. The dialysis operation was carried out with a cellulose sleeve and was performed at the room temperature for few days. After the dialysis, the keratin was recovered from the solution by drying in an electric oven at 80^{o}C for 4 hours.

II.2. Preparation of Keratin-Urea-Formaldehyde Resin

25% of keratin and 45 g of urea was charged into a glass reactor containing 200 ml of 30% aqueous formaldehyde and the mixture was neutralized to pH of 7 using 10 ml of sodium hydroxide solution. The reaction mixture was stirred continuously using electric powered stirrer throughout the reaction time for 2 hours and later was heated at reflux for ten minutes after which the reaction mixture was acidified with 0.26 ml of acetic acid. The mixture was heated to boiling point for another 3 hours after which the final resinous product was vacuum concentrated until a desired viscosity of 280 centipoises was obtained. The experiment was repeated twice by varying the quantity of keratin to 50 and 75 % respectively. This procedure was also repeated using only urea and formaldehyde without keratin. The viscosity, specific gravity, pH, total solid content, and gel time of keratin modified urea formaldehyde resins was determined according to Atapex [6].

III. Results and Discussion

From Table I it can be seen that the pH of all the resin samples were found to be between the ranges of 8.8 – 9.1 indicating that the resins are alkaline. It can also be seen that the viscosity at 25^{o}C of the keratin modified resin is higher than the unmodified ones. This may be due to inclusion of keratin in the modified samples. This is in agreement with the fact that the higher the viscosity the better the reactivity of the resin [6].

TABLE I
PROPERTIES OF MODIFIED AND UNMODIFIED RESIN SAMPLES

Resin samples	pH at 25^{o} C	Viscosity at 25^{o}C (cp)	TSC at 105^{o}C/2hrs (%)	Relative density (g/cm3)	Gel time at 100^{o}C (s)
A (Unmodified)	8.8	260	62.0	1.45	180
B (Modified)	9.0	280	63.5	1.34	167
C (Modified)	8.9	300	66.0	1.29	120
D (Modified)	9.1	330	69.0	1.25	82

The total solids content of the resin samples as shown in Table I indicates that the resins have different total solids content, with samples A, B, C, and D having 62.0%, 63.5%, 66.0% and 69.0% respectively. All the values are greater than 45% which is the minimum value and this is recommended by Atapex technical data for timber and plywood. It is also a well known fact that the more the solids content the better the resin[6].Generally the purpose of determining the gel time of a resin for use as adhesive is to ascertain the resins reactivity during hot pressing and storage. Table I shows that sample A has gel time of 180 sec, while the modified samples have gel time of 167, 120 and 82 secs respectively. This implies that sample D of the modified resin has the best reactivity followed by C and lastly sample B. Thus the behaviour of the modified resins showed a great improvement in accordance with Atapex [6].

From the same table, the modified resin samples of B, C and D have relative densities of 1.34, 1.29 and 1.25 respectively while the unmodified sample A has the relative density of 1.45. Thus the relative density of modified resin is in agreement with the standard, compared to the unmodified resin. Thus keratin inclusion in the resin could potentially lower the resin relative density. This is in accordance with Saheb and Jog [7] that using a natural fiber in such application will definitely benefit from weight reduction since keratin is very light. Because the modified resin is made of about 25%, 50% and 75% keratin [8], less urea are needed to produce it, according to Durham [9].

IV. Conclusion

From the analysis carried out in the development and characterization of keratin-modified urea-formaldehyde petrochemicals, it can be concluded that, modified urea-formaldehyde resin showed an improved qualities than the neat urea-formaldehyde resins. This is a good indication that the resins stability and durability, as well as its hydrophobicity, increases with the amount of keratin present in the resin. This is due to the content of disulphide bonds and the great amount of hydrophobic amino–acids in keratin [10]. It can also be concluded that a high amount of keratin in the resin sample means a resin with better stability, durability and hydrophobicity. Interestingly, the inclusion of keratin in the resin has

resulted in a significant improvement in the properties of the resin.

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