(REFEREED RESEARCH)

CHEMICAL TREATMENT OF CHICKEN FEATHER PRIOR TO USE AS FILLING MATERIAL

DOLGU MALZEMESİ OLARAK KULLANIM ÖNCESİ TAVUK TÜYLERİNİN KİMYASAL MUAMELESİ

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ABSTRACT

In this study, an alternative combined method to treat chicken feathers to be used as a filling material has been developed. The proposed method for treatment of chicken feathers is based on the combination of aldehyde treatment and acid-alum method including less harmful chemical usage with fewer number of processing steps. A number of international standard tests such as oxygen index number, turbidity, moisture, content analysis (composition), odor test have been applied on the treated chicken feathers in order to determine whether it is suitable to be used as a filling material. Results showed that with less harmful chemical usage, presenting chicken feathers with fluffy structure and almost white in color after treatment, the proposed method offers a good alternative in treatment of chicken feathers by providing the demanded physical properties.

Keywords: Chemical treatment, chicken feather, filling material, oxygen index number, turbidity

ÖZET

Bu çalışmada, dolgu malzemesi olarak kullanılacak olan tavuk tüylerinin terbiyesi için alternatif kombine metot geliştirilmiştir. Tavuk tüylerinin terbiyesi için önerilen metot, aldehit ve asit-şap metotlarının kombinasyonuna dayalı olup daha az sayıda işlem adımı ve daha az zararlı kimyasalların kullanımını içermektedir. Dolgu malzemesi olarak kullanım uygunluğunun tespit edilmesi için terbiye işlemi gören tavuk tüylerine, oksijen indeks sayısı, bulanıklık, nem, içerik analizi (tüy kompozisyonu) ve koku testi gibi birçok uluslararası standart test uygulanmıştır. Sonuçlar, önerilen metodun az zararlı kimyasal kullanımı ile birlikte kabarık yapıda ve neredeyse tamamen beyaz renkte tavuk tüyü elde edilmesini sağladığını ve istenen fiziksel özellikleri sağlayarak tavuk tüyünün terbiyesinde iyi bir alternatif oluşturduğunu göstermektedir.

Anahtar Kelimeler: Kimyasal muamele, tavuk tüyü, dolgu malzemesi, oksijen indeks sayısı, bulanıklık

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1. INTRODUCTİON

Filling materials are generally used for trapping air and providing insulation. The insulation and comfort levels mainly depend on the type and amount of filling material as well as on filling method.

There are two types of filling materials: i) synthetic fibers and, ii) natural fibers. Polyester is the most common synthetic filling fiber because of its non-allergic and anti-odor properties. Moreover, it has low thermal conductivity, good compressibility, and low moisture absorption. The insulation value depends on polymer's thickness, density, uniformity and bonding techniques. The transformation parameters from polymers to staple fiber like crimp, texture, cross-sectional shape, size and number also affect the insulation properties. Apart from synthetics, duck and goose feathers are the most common natural filling fibers, but they are highly expensive compared to synthetics. Down filling materials are the mixture of down components including nestling down, plumules, down fibers, feathers and feather residue. Down is light, thin, soft, and fluffy [1, 2]. Down, nestling down, and plumules are the most valuable parts of any plumage product. Their structure is three dimensional and since their clusters are composed of interlocking fine barbs, they attach to each other and thus create millions of tiny air spaces trapping air. Down, nestling down, and

plumules are defined as down cluster which is a new term proposed by the IDFL. On the other hand, the detached barbs from down or the basal end of waterfowl feather quill shafts are down fibers whereas the outgrowth forming the contour and external covering of fowl is defined as the feather [2]. Having two dimensional structures, down fibers and feathers cannot provide efficient insulation as down clusters. However, down cluster entangles when wet and causes decrease in insulation quality and drying behavior. Moreover, after a while, unpleasant odor and allergic reactions might occur with the entangled down clusters.

Apart from duck and goose feathers, chicken feathers can be alternative natural option due to lower price and high availability as being waste of a highly consumable product in food industry [3]. Moreover, duck and goose feathers are collected from the animals when they are alive, and there is growing public opposition against use of such feathers.

Chicken feathers have round hollow quill from which the fine, thread-like barbs extend on both sides, branching to form barbules. Through the hooklets on the barbules, the barbs and barbules interlock to form a network containing a large number of air channels. Thanks to this structure, when used as filling material in beds, it causes an insulating air layer between the body and the surrounding which results in warmth in cold weather. Fine air channels together with hydrophilic feathers further contribute to better transport of moisture [4]. However, the fundamental difference compared to goose and duck feathers is their thinner and straighter quills which cause lower elasticity, less insulating capacity and sensitivity to stress [5].

Chicken feathers have wide usage in technical textiles applications, and keratin in chicken feather has been used for manufacturing artificial hair. The behavior of the chicken feather is mainly studied by the researchers as a reinforcing material for composite structures [6-12]. In order to increase the elasticity, insulation and strength, chicken feathers are chemically treated. There are two very popular approaches, namely aldehyde treatment based on a patented process [13] and acid-alum method based on a Keracurl ®treatment [14]. Aldehyde treatment method includes removal of impurities by washing, treatment with a haemolytic agent and a second washing using nonyl-phenol non-inonic detergant followed by keratin and aldehyde treatment to which chromium fluoride is added as well. [13]. The treatment is finalized with a number of rinsing cycles. Haemolytic agents cause increase in rate of red blood cell destruction, and its mechanism is explained in detail elsewhere [15]. High rate of red blood cell destruction may cause haemolytic anaemia [16]. Nonyl-phenol detergents are banned in many countries, and chromium fluoride is a known toxic chemical. It is apparent that aldehyde treatment of chicken feathers comprise use of many hazardous chemicals, and high level of protection as well as expertise is demanded during chicken feather treatment using aldehyde treatment method. On the other hand, acid-alum method comprises plasticization of chicken feathers in diluted acid and alum solution. Sulfuric acid is used, and the treatment time is at least 90 minutes, followed by a 20 minutes washing step at 60-70^{0}C with soda ash, and several rinsing steps until chicken feathers are completely neutralized and free from residual chemicals [14]. In general, washing process is conducted with running water and partial C_2H_5OH to obtain clean, sanitized and odor free chicken feathers [3]. Acid-alum method is a timely process, and high amount of waste water must be treated prior to discharge. Moreover, sulfuric acid is corrosive, and demands special equipment during use and storage. Both methods include use of expensive and environmentally harmful chemicals and lots of water, thus an alternative comprising fewer treatment steps and use of less harmful chemicals is highly demanded. In this study, an alternative combined method to prepare chicken feathers to be used as a filling material has been developed.

2. EXPERİMENTAL

2.1. Materials

Chicken Feathers are kindly supplied as biowaste from a chicken food company. The chemicals used for processing and testing include EDTA (chelating agent, Mw= 372.240 g/mol), aluminum sulfate-18- hydrate (Mw= 666.420 g/mol), sodium carbonate (Mw= 105.989 g/mol), acetic acid (Mw= 60.05 g/mol), potassium permanganate (Mw= 158.034 g/mol), trichloroethylene (Mw=131.401 g/mol) supplied by Merck® and ECE standard reference detergent including linear sodium alkyl benzene sulphonate (8%), ethoxylated tallow alcohol (2.9%), sodium soap (3.5 %), sodium tripolyphosphate (43.7%), sodium silicate (7.5%), magnesium silicate(1.9%), carboxy methyl cellulose(1.2%), etylene diamine tetra acetic acid (0.2%), sodium sulphate (21.2%) and water (9.9%). All chemicals used are reagent grade with the exception of standard reference detergent. All concentrations are expressed as % (weight /weight). Plain weave cotton fabric with a basis weight of 140 g/m^2 (32 ends/cm x 36 ends/cm) was used to produce cotton fabric bags for loading chicken feather inside the washing machine.

2.2. Chemical Treatment Method

The proposed method for preparation of chicken feathers used in this study is based on the combination of aldehyde treatment and acid-alum methods. Aldehyde treatment comprises soaking of chicken feathers for 10 minutes at 40-50^{0}C in 1 g/L of haemolytic agent solution, laundering with 0.25% nonyl-phenol non-ionic detergent at 40-50^{0}C for 20 minutes (or dry cleaning), treatment with 1% $Na_3PO_4.12H_2O$ at 40-50^{0}C up to 30 minutes at pH 6-7 with keratin as stabilizing agent, immersion in 1% alpha-hydroxyadipaldehyde + 0.1% $Al_2(SO_4)_3$ + 0. 05% chromium fluoride (pH 2-4) at 40-50^{0}C for 30 minutes, followed by rinsing and drying in open air. On the other hand, acid-alum method comprises plasticization of chicken feathers in diluted acid and alum solution. The acidic treatment solution is prepared by addition of water, followed by stepwise addition of 2% sulfuric acid and 2% aluminum sulfate (or alum). The chicken feathers are digested in the acidic solution for at least 90 minutes, and then the solution is discharged. The feathers are then treated for at least 20 minutes at pH 5-6 with mechanical agitation in water at 60-70^{0}C, and soda ash is added in order to precipitate aluminum hydroxide. Following warm water treatment, the feathers are rinsed several times until the precipitate disappears. Finally, the feathers are rinsed thoroughly until completely free from acid, and dried.

In order to offer an acceptable alternative process, some steps from both methods were selected. Moreover, alternative chemicals were used in place of harmful ones. EDTA was used in place of haemolytic agent, and ECE standard detergent was used in place of nonyl-phenol non-ionic detergent. The selected steps from both methods as well as alternative chemicals selected are summarized in Figure 1. The developed method alternative to aldehyde and acid-alum methods is given in Figure 2. According to the developed method, firstly, 4 Kg of feather was put in 25 L containers with 20 L water and 3 g/L of standard detergent, 3g/L of chelating agent were added stepwise, and feathers were kept in the container for 1 hour without mechanical agitation. The chicken feathers are filtered and the wash liquor is collected for reuse in laundry. Cotton fabric bags of selected sizes are stitched, and chicken feathers were loaded in the bags after filtering. The bags filled with feather were laundered at 60°C at 600 rpm for 1 hour by using the collected wash liquor. Aluminum sulfate solution at pH 6 was prepared using acetic acid. After laundry, the feathers are kept in 2% aluminum sulfate solution for 5 minutes, and further kept for 5 minutes after addition of 1% sodium carbonate into the solution. After filtering and rinsing, feathers are treated with trichloroethylene at room temperature to remove oily stains. Finally, the feathers are filtered and left to dry at room temperature for 24 hours.

2.3. Analysis Methods

In order to present that the alternative chicken feather treatment method offers treated chicken feathers that are acceptable to be used as filling material, a number of tests were performed, and their results were presented.

2.3.1. Oxygen Index Number Test

The oxygen index number indicates product cleanliness by providing a measurement of oxidizable and soluble material present in the filtrate of the aqueous extract of the material. Chicken feather plumage samples were put into water and tumbled at room temperature for 60 min. The resulting suspension was filtered and mixed with sulphuric acid. Then, the excess water from the chicken feathers was titrated with potassium permanganate. The test was done according to BS EN 1162:1999 test standard [17].

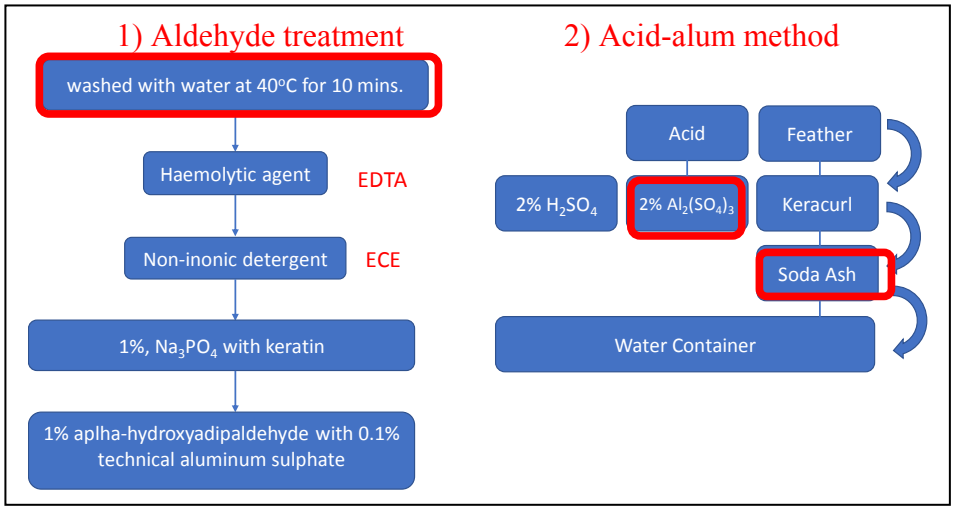

Figure 1. Aldehyde treatment, acid-alum method for preparation of chicken feather together with selected steps and alternative chemicals

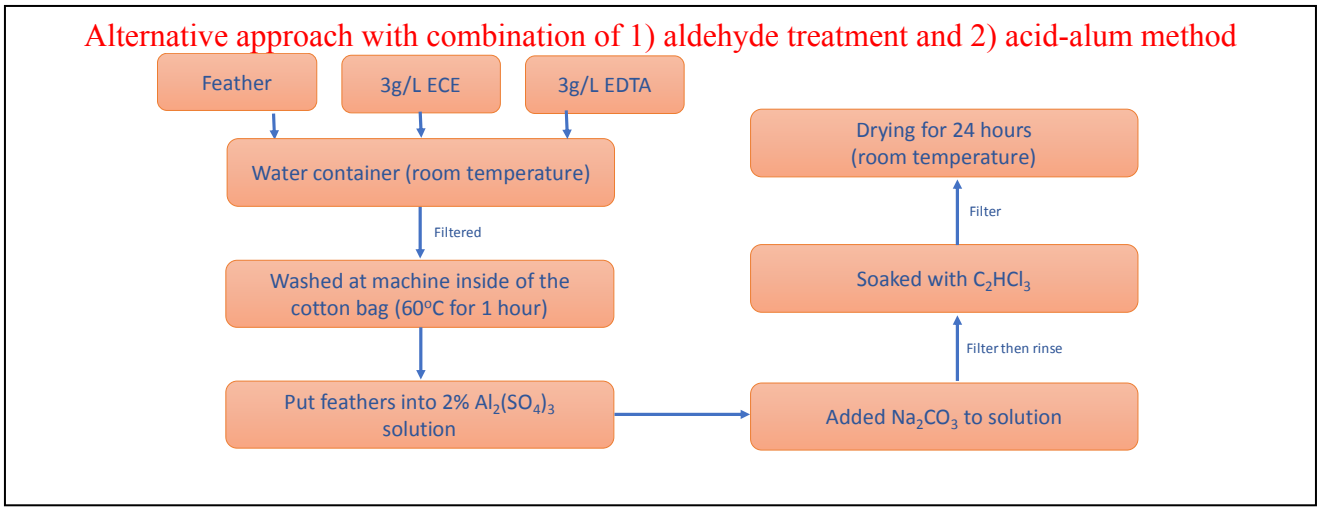

Figure 2. The developed method for treatment of chicken feather

The oxygen index number is calculated as follows:

$$I = 80 \times (A-B) \quad (1)$$

where:

I is the oxygen index number; A is the quantity of 0,02 mol/L potassium permanganate used for the test specimen, in milliliters; B is the quantity of 0,02 mol/L potassium permanganate used for the blank test, in milliliters.

2.3.2. Turbidity

Turbidity shows the reduction of transparency of the filtrate suspension caused by the presence of undissolved and dissolved matter. 10 g of conditioned test specimens were put into a tumble jar containing 1 L of water, and tumbled for 60 minutes followed by filtration. The filtrate is poured into container in order to observe the corresponding height of the poured filtrate in the container when the cross is invisible. This procedure was done according to BS EN 1164:1999 test standard [18].

2.3.3. Moisture Content

Moisture content is the percentage of water held in a sample. 5 grams of the plumage is transferred to uncovered container for testing. The container is then placed and covered in the oven and dried for 130 minutes. After cooling to room temperature the covered container is weighed. The procedure has been repeated until a constant mass, within 1 mg, is obtained. The moisture content is determined from the weight of the dried sample. This procedure was done according to BS EN 1161:1996 test standard [19].

The moisture content expressed as a percentage is calculated as follows:

$$M_c\ \% = [(A-B) / (A-C)] \times 100 \quad (2)$$

where;

M_c is the moisture content in percent; A is the mass of the container with lid and undried individual sample; B is the mass of the container with lid and dried individual sample; C is the mass of the container with a dried lid.

2.3.4. Content Analysis

A mixture of random samples from the chicken feathers was placed in the sorting cabinet and was separated by hand into the following components: i) Down clusters, plumules, ii) Down fiber, iii) Feather fiber. Each component was weighed to the nearest 0.2 mg, and in the case of the double tests, the results were averaged. This procedure was done according to BS EN 12131:1998 test standard [20].

2.3.5. Odor Test

The odor test indicates potential odor problems in a filling material. Material was soaked in water and warmed for 24 hours according to IDFL (International Down and Feather Laboratories) Testing Regulations. Then, material was smelled to determine if a "putrid" condition exists. 15 female and 15 male non-smokers of ages ranging between 18 and 25 participated in odor test. The participants were asked to grade the smell as “putrid smell”, “very bad smell”, “bad smell”, “faint smell”, or “no putrid smell”.

3. RESULTS

A big visual difference is observed between the chicken feather samples before and after application of the proposed chemical treatment. Before chemical treatment, the feathers aggregated together, looked yellowish accompanied with a bed smell. However, after chemical treatment, they became fluffy and almost white in color. Moreover, no disturbing smell was observed. The differences between chicken feather samples before and after chemical treatment can apparently be seen in Figure 3.

The oxygen index number test results are shown in Table 1. According to test results based on IDFL regulations and EN 1162, the oxygen index number values were within the acceptable range for chicken feathers to be used as filling materials.

Figure 3. Images of chicken feather before and after chemical treatment

Table 1. Oxygen index number test results

Samples #	Potassium Permanganate used (mL)	Oxygen Index Number
Sample 1 (distilled water)	0.22	13.6
Sample 1 (chicken)	0.39	
Sample 2 (distilled water)	0.27	12.0
Sample 2 (chicken)	0.42	
Sample 3 (distilled water)	0.25	12.8
Sample 3 (chicken)	0.41	

Turbidity test results showed that although all the filtrate was poured the cross was visible throughout the test, which means that no turbidity occurred. Test results indicated that the chicken feather was completely free from impurities after treatment according to newly developed method.

The moisture content values of chemically treated chicken feathers are given in Table 2. According to test results based on IDFL regulations and EN 1162, the moisture content values were within the acceptable range for chicken feathers to be used as filling materials.

Table 2. Moisture Content Test Results

Moisture Content (%)	A	B	C
4.23	13.36	12.07	7.84

According to content analysis test results, it was found that the chicken feather consisted of approximately 30% down clusters and plumules, %30 feather fiber, and %40 down fiber. The content analysis showed that there was sufficient distribution among the three types such that insulation would be achieved without entanglement of the feather even when wet.

Prior to treatment, all participants of the odor test reported that the material had “putrid smell” or “very bad smell”. However, the responses just after the treatment and 24 hours after the treatment were all “no putrid smell”. Odor test results showed that no putrid smell was observed after 24 hours which indicates that such treated chicken feather can be suitable for outdoor applications.

CONCLUSIONS

Although duck and goose feathers are commonly used filling materials with superior insulation and comfort properties, there is growing public opposition against their use mainly due to their harvesting of feathers being carried when animals are alive. Synthetic fibers offer a weak nominee as their waste management is an environmental issue. Considering high amount of chicken feather bio-waste coming from food industry, chicken feathers may offer a good natural alternative if they are treated properly. In this study, a chemical process is developed for treatment of chicken feathers with demanded physical properties to be used as filling material. The treated chicken feathers were shown to achieve no turbidity, demanded moisture, acceptable oxygen index number with no disturbing odor, almost white color and fluffy structure. Moreover, offering less harmful chemicals and fewer processing steps when compared to conventional chicken treatment methods, it can be used as alternative method for treatment of chicken feathers to be used as filling material.

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