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Recovery of Waste-Water from Wheat Washing Operation*

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ABSTRACT

Washing wheat for a clean and hygienic product is a critical step in cereal processing plants. High amounts of water are used and discharged without any treatment in these plants. This study claims that wastewater of a cereal processing plant can be reused by the treatment columns. In this study, washing (20°C) was made using water (ratio of water to wheat, 1:2). The waste-water of wheat washing was treated with filtration, centrifugation, column (containing sand, activated carbon and resin), and UV. The properties of water (DO, BOD_5, color values (CIE L*, CIE a*, CIE b*, CIE YI), pH, turbidity, conductivity, total solid content (TSC), Brix and microbial load) were measured to determine the effectiveness of the recovering treatments. Results indicated that the treatments were significantly ($P<0.05$) effective on the reduction of the BOD_5 values from 311.5 to 169.9 mg/L. The treatments improved the color of water. Decrease in TSC, Brix, conductivity and turbidity values illustrated the removal of wastes with the treatments. Overall water recovery was 53%.

Keywords: Waste-water, Recovery, Wheat, Washing, Reuse

Buğday Yıkama İşleminde Atık Suyun Geri Dönüşümü

ÖZET

Hububat işleyen fabrikalarda buğdayın temizlenmesi için yıkanması önemli işlemlerden birisidir. Bu tip fabrikalarda bol miktarda su yıkama işlemi için kullanılır ve atık su olarak uzaklaştırılır. Çalışma, bu atık suyun temizleme kolonları ile tekrar kullanımı ile ilgilidir. Çalışmada yıkama işlemi (20°C) buğday su oranı 2'ye 1 olacak şekilde yapılmıştır. Elde edilen atık su filtreleme, santrifüj, temizleme kolonu (kum, aktif karbon ve reçine içermektedir) ve UV aşamaları ile temizlenmiştir. Temizleme işlemlerinin geri dönüşüme etkilerinin belirlenmesi amacıyla elde edilen suda çözünmüş oksijen miktarı (ÇO), biyolojik oksijen ihtiyacı ($BOİ_5$), renk değerleri (CIE L*, a*, b*, CIE YI), pH, bulanıklık, iletkenlik, toplam katı madde, briks ve mikrobiyal yük değerleri ölçülmüştür. Temizleme işlemlerinin $BOİ_5$ değerlerinin 311.5' ten 169.9 mg/L'ye azaltılmasında önemli bir etkiye ($P<0.05$) sahip olduğu görülmüştür. Ayrıca temizleme işlemleri suyun renginde de düzelmeye etki etmiştir. Toplam katı madde, briks, iletkenlik ve bulanıklık değerlerindeki azalma ise temizleme işleminde katı atıkların uzaklaştırıldığını göstermiştir. Toplam geri dönüşüm miktarı ise %53 olarak belirlenmiştir.

Anahtar Kelimeler: Atık su, Geri dönüşüm, Buğday, Yıkama, Yeniden kullanma

INTRODUCTION

Increasing industrial production and water pollution improve the importance of the sources of water. The world is confronted by an ever increasing shortage of water, especially in arid and semiarid regions such as Africa, South Asia, Southern Europe, and the Middle East. In many of these regions, freshwater is limited for irrigation, and therefore, the reuse of treated or untreated wastewater is the sole water source for agriculture. However, standards are required to ensure safe use of wastewater and to avoid biological risks to the human population [1]. Environmental principles of policy have become increasingly important in water management, both internationally as well as on the national level [2]. International and national legal regulations are made in order to control of the pollution of natural water sources and to control of the waste-water disposal. Discharge of inorganic and organic pollutants into water bodies has greatly affected the ecological balance and cause harmful effects on flora [3]. In the food industry water recycling is applied; olive oil [4], beverage industry [5, 6], fishmeal [7, 8], poultry and sausage production industry [9-12] and dairy industry [13]. Researchers have shown there are different solutions and techniques for the water treatment and recovery such as using plants to remove material; [14]; sedimentation ponds [15] and fermentation; [16] etc. Others [17] have concentrated on the recovery of usable ingredients from waste water such as carotenoids rather than water purification. In addition, El Hajjouji et al. [18] and Vrhovšek et al. [19] studied on the some recoveries techniques in the waste product. Also,Casani and Knochel [20] published a HACCP study to reuse waste water in the food industry. Many researchers [21, 22] concluded about the need of a treatment procedure of waste-water released from the food plants.

Wastewater generated by food processing includes high Biological Oxygen Demand (BOD), high levels of dissolved and/or suspended solids, nutrients, and minerals. In the processing food, the Biological Oxygen Demand and Chemical Oxygen Demand (COD) are major problems. The waste compounds are generally nutrients and they can be recovered to reuse.

Cereal processing plants discharge high amount of wastewater due to washing operation. This wastewater contains high amount of BOD_5 value namely biodegradable nutrients and other impurities. In order to recover this water, a treatment process is required. According to literature survey, there is no study for the level of nutrients and impurities in wastewater and its treatment procedure for cereal industry. So this study has a vital role to fulfill that space. The aim of this study is to develop a treatment system to recover water from the washing operation of wheat.

MATERIALS AND METHODS

Raw Material

Wheat, *Triticum durum* cultivar was obtained from a local bulgur producer in Gaziantep, Turkey.

Washing Operation

Two hundred grams of wheat was washed in a beaker for 5 min at 20°C (wheat/water: 2/1). Then, the washing water and wheat were separated using a wire-screen (3.2 mm hole diameter).

Waste-Water Treatments

The washing water was first filtered using a coarse filter paper (thickness: 0.285 mm, weight: 73g/m^2) to separate the coarse particles. Then, sedimentation was made as a second treatment at 8000 rpm for 20 minutes using a centrifuge (Hettich, Roto Silenta III, Germany) to separate some insoluble fine particles. Then, the supernatant liquid was decanted without disturbing the precipitate.

At the third step, a column filtration was used, which contains sand, activated carbon and resin (Figure 1). The column was wetted at first time using distilled water for overnight. Sand (6 mL, particle size range= 2.2-2.6 mm) was used to capture any other coarse or fine particle remaining after the filtration and centrifugation. Sand, at the same time, adjusts the flow rate before the activated carbon and resin in the column filtration. The column diameter was 1.28 cm.

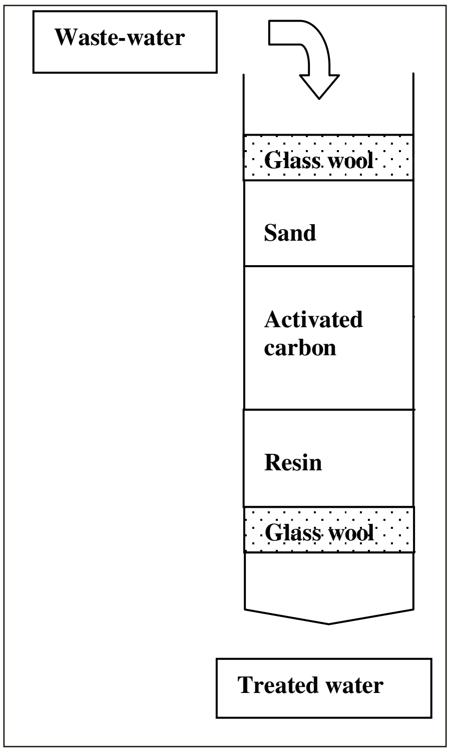

Figure 1. Column system for waste-water

Activated carbon (Norit activated carbons, Norit, USA), (9 mL, bulk density =0.192-0.48 g/cm^3, black powder with no odor, insoluble in water) was used to filter some harmful chemicals, odors and some color pigments from the waste-water.

Resin (Lewatit S 1468, Bayer, Germany), (7 mL, cross-linked polystyrene divinylbenzene; particle size range= +1.2 mm <5%, -0.3 mm <1%; specific gravity= 1.27; spherical bead) was used to seperate ionic compounds in the waste-water. Finally, the waste-water was exposed to UV light of 30 W (Philips, TUV/30W, Holland) at 254 nm for 2 hours to inactivate microorganisms.

Experimental

Measurements of Dissolved Oxygen (DO), Conductivity, and BOD$_5$

Dissolved oxygen and conductivity were measured at 20°C with a multi-meter (HQ40, Hach, USA). Before and after the treatments, Eq. 1 was used to calculate BOD$_5$ value. In the present study, according to the trial results, the washing waste-water had a high microbial load; therefore, there were no need to add seed culture to determine the BOD$_5$ during the experiments. The waste-water was diluted and aerated for BOD$_5$ test. To determine BOD$_5$ value of waste-water of the washing operation, the samples were diluted to 1, 2 and 5 %. Then, it was aerated with a pump and DO was measured. The samples were stored under anaerobic condition.

$$BOD_5(mg/l) = \frac{DO_1 - DO_2}{P} \qquad (1)$$

where, DO_1 and DO_2 were dissolved oxygen of diluted sample immediately after preparation (t=0) and 5 days (t=5 days) (mg/L), respectively. P was the fraction of waste-water sample volume to total combined volume.

Measurement of Color

Color of the water samples were measured at D65 using Hunter Lab Colorimeter (Colorflex, USA). Before the color measurement, white standard tile was used to calibrate colorimeter (L= 93.01, a=-1.11, b=1.30). Water samples were measured through an optical glass cell.

In the Hunter scale, CIE L* measures lightness and various from 100 for perfect white to 0 black, approximately as the eye could evaluate it. The chromatically (CIE a* and CIE b* values) gives understable designation of color as follow; "CIE a*" measures redness when positive, gray when zero and greenness when negative. "CIE b*" measures yellowness when positive, gray when zero and blueness when negative. CIE YI (yellowness index) visually; yellowness associated with scorching, soiling, and general product degradation by light chemical exposure, and processing. Yellowness indices are used chiefly to measure these types of degradation [23].

Measurements of pH, Brix, Total Solid Content (TSC) and Turbidity

The pH, Brix and turbidity of waste-water were measured at 20°C using a pH-meter (Jenway-3010, UK), refractometer (PTR 46X, Index Instrument Ltd., England) and a visible light spectrophotometer at 500 nm [24] (Pharmacia, LKB-Novaspec II, UK), respectively.

Total solid content (%) (TSC) of washing waste-water and treated water were measured using a visible light spectrophotometer using 500 nm. in absorbance mode (Pharmacia, LKB-Novaspec II, UK). As a note, pH of wheat was measured using 20 g of ground wheat in 20 ml of water to determine initial pH value of product.

Determination of Microbial Load

Aerobic plate count was made using Plate Count Agar (PCA, Merck, Darmstadt, Germany) with the aerobic spread plate count method as described in Erkeland, Roovers, Klomp, Valkhof, Aarts and Touw [25].

Coliform was determined with the presumptive test Most Probable Number (MPN) method as described in Erkkilä, Herrington, Mozaffarian and Lichtenstein [26] using Lauryl Sulfate Trypose Broth (LSTB, Merck, and Darmstadt, Germany).

Measurement of Moisture Content

The moisture content of wheat was measured at 105°C using the oven method [27].

Determinations of Protein Content

Kjeldahl method was used to determine the protein content of waste-water samples and wheat [27].

Determinations of Ash Content

The ash contents of wheat and waste-water were measured at 900°C using AOAC method [27].

Determinations of Starch (Ewer's Method)

Starch was hydrolyzed with HCl then the amount of starch was measured with a polarimeter (Polaar 3000, Optical Activity Ltd., England). Samples (1.25g) were treated with 12.5 mL of 1% HCl (Merck, Germany) in a 25 mL flask and shook. The mixture was kept for 15 minutes in water bath at 95-100°C. During the heating period, the mixture was shaken continually. Then, 7.5 mL of distilled water was added and cooled to the room temperature. In order to obtain a precipitate of free nitrogenous matter, 2.5 mL of 4% phosphor-wolfram acid (Merck, Germany) was poured into 2 dm of polarization tube and polarization value was determined by using the polarimeter. Percent starch calculated by using Eq. 2 [28].

$$\% \text{ Starch} = \frac{V_{TS} \times a_p}{A^{20}{}_D \times L_p \times W_s} \times 100 \qquad (2)$$

where, VTS is total volume of sample (mL), a_p is polarization value, A20D is conversation factor (specific rotation) of Ewer's method for starch (182.7 / (dm.g/mL)), L_p is length of polarization tube (dm), W_s is weight of sample (g).

Statistical Analysis

ANOVA was performed for the predicted data to determine the significant differences (P<0.05). Duncan multiple range tests were carried out. The experiments were replicated and the measurements were duplicated.

RESULTS and DISCUSSION

Practically wheat comes from field that should be cleaned using a dry (screening, aspiration, air channels) and wet processing (washing) before the operations in the cereal processing. Dust, soil and other dirty materials cause healthy risk and dirtiness during the operations. Especially, these materials affect the color of product and dissolve in the cooking water then absorbed by the kernel. Therefore, the washing operation is vital in the cereal processing. Recently, in EU due to environmental problem and waste-water treatment costs, washing operation is started to cancel in flour and semolina mills.

For example the BOD_5 value of waste-water obtained from a bulgur factory washing unit is 1400 mg/l. This big value of BOD_5 is due to the usage of water to wash wheat, again-and-again in plants (additionally, the accumulation of washing water in the pool of equipment). Therefore, industrially discharged waste-water has extremely high BOD_5 value.

In the present study, the waste-water obtained from the washing operation was treated using the different recovering techniques (coarse filtration with paper filter, centrifugation, sand filtration, activated carbon filtration, resin filtration and UV). The properties of wheat used in the experiments are given in Table 1.

Table 1. The properties of wheat used in the experiments

Properties		Values	SD (n=4)
Color	CIE L*	51.13	0.0565
	CIE a*	8.82	0.2757
	CIE b*	25.26	0.2828
	CIE YI	74.95	0.0707
	Moisture content (%, w.b.)	9.13	0.0070
	pH	6.44	0.0261
	Protein content (%, d.b.)	13.07	0.0212
	Ash content (%, d.b.)	1.76	0.0021
	Starch content (%)	52.70	0.0000

Change in BOD_5 and DO

It was found that the treatment processes were significantly effective (P<0.05) on the BOD_5 and DO values, which decreased after the treatments (Table 2). DO value of the distilled water used for the washing operation in the experiments was 7.72 mg/l. It was moderate level when compared to the literature value i.e. as max. 9.2 mg/l at 20℃ [29]. DO value of washing waste-water was determined as 6.92 mg/l. This decrease in the DO value was due to the effect of organic matters in the waste-water and the pH value which caused to decrease in the solubility of the oxygen. After the treatments of the waste-water, the solubility of oxygen was very low compared with the washing waste-water due to the effect of column material e.g. resin, activate carbon.

Table 2. Values of BOD_5, DO, Conductivity, TSC, Brix, Turbidity, pH, and Microbial Count

	Wheat		Washing waste-water		After treatments	
	Average	SD (n=4)	Average	SD (n=4)	Average	SD (n=4)
BOD_5 (mg/L)			311.5	25.4558	169.90	36.9110
DO (mg/L)			6.92	0.1414	1.96	0.0283
Conductivity (S/mL)			0.001514	0.0000	0.00131	0.0000
TSC %			0.455	0.0071	0.265	0.0071
Brix			0.455	0.0071	0.260	0.0000
Turbidity (500 nm)			0.965	0.0071	0.169	0.0014
pH	6.45	0.0071	6.33	0.0141	7.03	0.0071
Total aerobic count (cfu)			4116750	0.0000	15000	0.0000
Total coliform (cfu)			42.5	0.7070	1.75	0.3540

The BOD_5 value of the washing water before the treatments was 311.5 mg/L. After the treatments, it decreased to 169.9 mg/l. The decrease in BOD_5 value showed that decrease in organic constituents.
The treatments used in this study decreased the biodegradable substances in the waste-water (Table 2.). Therefore, the value of the BOD_5 of the treated waste-water was consistent with these statements.

Change in Color

Many of the foreign substances in the washing waste-water provide the darkness of water. Additionally, coloring compounds, which leached into water, leads to dark color in the waste-water as explained by Skuratovich et al. [24], Bayram et al. [30]. As a result, the treatments reduced the coloring compound content in the water, which is significant because it causes the darkness/dirtiness in water.

In general, lower CIE YI value shows especially greater clarity (cleanness or clearness) in water. The increase in CIE YI value is opposite to decrease in the lightness (CIE L* value) and in parallel with the CIE b* value. The losses of clarity and lightness could be correlated with the leaching of the soluble solids (pigments, organic materials etc.) and causes the darkness in water [24,30, 31].

The treatment processes were significantly effective (P<0.05) on color changes (Figure 2). The clarity of the treated water was higher than untreated washing waste-water, which means the higher CIE L* values for the treated water.

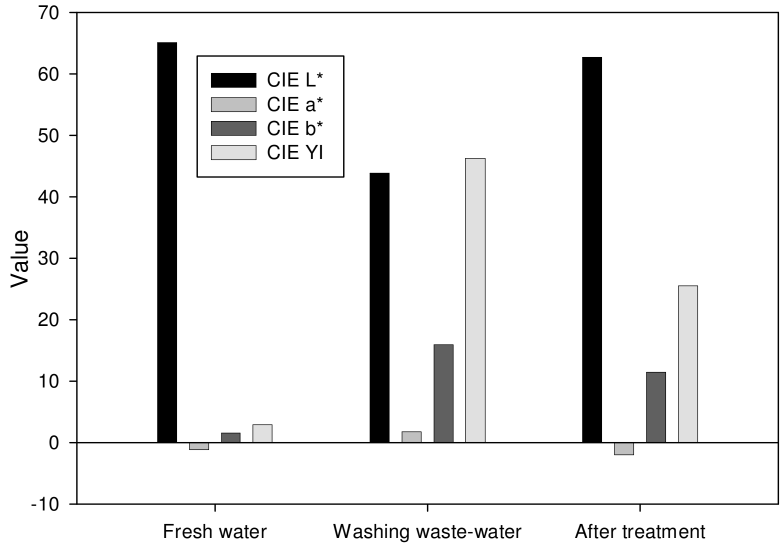

Figure 2. CIE L*, CIE a*, CIE b* of fresh water, waste-water and water after treatments

Figure 2 shows that the CIE L* value increased from 43.87 to 62.67. Decreasing CIE a* value shows that the pigment concentration, were reduced by the treatments. As expected, the CIE YI value inversely was affected from the treatment processes by the decreasing from 46.29 to 25.58. The CIE b* value was parallel to CIE YI value and decreased from 15.99 to 11.51.

Change in pH

Results showed (Table 2.) that the treatment processes were significantly effective (P<0.05) on the pH changes. The decrease in the pH of washing waste-water illustrated the leaching of some materials into the washing waste-water from the wheat. Also, same results were obtained by Granato et al. [4]. The increase in the pH of waste-water after the treatments most probably shows the elimination of acidic matters formerly leached from the wheat by the capturing ions in the column.

Change in Brix and TSC

Total solid content is the whole solids in the solution; as soluble and insoluble solids. Therefore, TSC should be higher than Brix than the results are consisted with this statement. The treatment processes were significantly effective (P<0.05) on Brix and TSC changes (Table 2). After the treatments as expected, water had a lower value of Brix and TSC due to trapping the solids by the filter and column. The treatment processes reduced the amount of soluble and insoluble solids in the waste-water. Especially, filtration, centrifugation and column materials formed bond with the solid components found in the waste-water.

Changes in Turbidity and Conductivity

It was found that the treatment processes were significantly effective (P<0.05) on the conductivity and turbidity changes. The color changes were also corrected with the turbidity results, which turbidity decreased from 0.970 to 0.168 (Table 2.). This result shows that turbidity forming compounds i.e. organic compounds were removed by the treatments. It was also correlated by the studies of Skuratovich et al. [24], Bayram et al. [30] and [31].

Conductivity is directly related with the ions in the solutions. In the present study, because of the resin found in the column, conductivity decreased. This result was also correlated with that of results of Brix, TSC and turbidity.

Change in Microbial Load

As shown in the Table 2, total number of microorganism and coliform (as CFU: coliform forming unit) in the waste-water reduced significantly (P<0.05) by the treatments especially with the UV which was advised by Hyer and Brown [32] for disinfection of food waste-waters.

Recoveries from the Washing Operation

The washing operation was made with two part wheat and one part of water. As shown in Table 3, 200 g wheat was washed with 100mL of water. After the washing operation, 72.8mL of water remained. The loss on the quantity of water was due to the absorption of water by wheat and solid wastes. The treatments were applied on the remained washing waste-water. After, the treatments, water quantity decreased to 38mL. Therefore, 36.8mL of water was lost during the treatment operations (72.8-38=36.8mL). During these operations, the dirty materials (solid wastes e.g. soil, dust etc.) were removed, which absorbed a certain amount of water, therefore water loss occurred. At the same time, all treatments were made at atmospheric conditions. Therefore, the evaporation of water was another possible reason. According to this calculation, 53% of water was recovered.

Table 3. Example of 100 mL water+ 200 g wheat washing operation

Tests applied (100 ml fresh water)				
Brix	TSC (%)	Turbidity	pH	DO(mg/l)
72.8 ml of washing wastewater remains				
0.45	0.45	0.97	6.33	6.8
38 ml of treated water as recovered water				
0.26	0.26	0.17	7.02	1.94

CONCLUSIONS

Waste-water of cereal plants is disposed to the environment. Waste-water of the cereal plants has a very high value of BOD5, which means that the high amount of nutrients that can be easily consumed by the microorganisms and can cause environment problems. It decreases the amount of the dissolved oxygen in the river and lake. Therefore, decreasing DO in the water affects the life of the plants and the animals. At the same time, microorganisms also increase the toxicity of the water.
After the treatment, recovered water (53%) from the washing operation can be reuse in the subsequent washing operation. Therefore, the treatments must be used in the cereal plants by simple ways.

This study shows that it is possible to clean and reuse the waste-water disposed from a cereal plant by a small treatment process. This recovery method can also be used in different cereal or legume producing plants. In these sectors, the washing operation is same based on washing technology, water quantity and raw material.

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