Production of Bio-ethanol from Potato Processing Wastewater using Membrane Technology

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Abstract: A potato processing industry use large quantity of water and therefore produces large liquid waste. Wastewater from the potato processing industry contain high concentration of chemical oxygen demand (COD) caused by the presence of starch and protein. In recent year membrane processes shows an effective alternative to traditional wastewater treatment processes for improving the efficiency and reducing the environmental impact in the food industry. Potatoes are cheap substrate for production of bioethanol, because it is rich in starch and require less processing than other grains. In this study, potato processing wastewater was treated by using reverse osmosis system. Experiments were carried out in order to compare each run of the reverse osmosis by varying operating conditions. It was found that optimum feed pressure for the treatment of potato processing wastewater was 10 kg/cm^2 using polyethersulphone reverse osmosis membrane. The rejection of 95.25% dissolved solid, 96.42% chemical oxygen demand(COD) and recovery of 0.72% starch were observed at 10 Kg/cm^2 feed pressure and transmembrane pressure of 8.5 Kg/cm^2. Different potato starch solution(5%, 10%, 15% and 20%) were prepared for optimum production of bioethanol. Starch solution of 10% was recommended for high scale production of ethanol. Moreover, 4.7% of bioethanol was produced from 10% starch solution using Saccharomyces cerevisiae (baker's yeast).

Keywords: Potato processing wastewater, Reverse osmosis, Enzyme hydrolysis, Fermentation, Bioethanol.

1. INTRODUCTION:

Wastewaters discharged from industries are one of the major sources of water pollution. Potato processing industry in India is mainly composed of three segments: potato chips, Alu Bhujia, french fries[6]. The worldwide production of potato is estimated as 3,64 Megatons in 2012[8]. India produces nearly 8% of the total global potato production, which is estimated as 29Megatons in 2012[8]. A huge amount of water is required for washing of potatoes therefore produce large liquid waste. Arapogluo et.al determined that for washing one tone of potato, 4.78m^3 water is required in a potato chips industry. This derives from 0.57m^3/tone of water is required for initial potato washing, 0.73m^3/tone of water required for the peeling, 0.28m^3/tone of water required for the water transport, 0.85m^3/tone of water required for slicing and soaking, 0.8m^3/tone of water required for final wash and 1.54m^3/tone of water required for the machines and floor washing. [2].

Advances in membranes technology have showed many advantages for treatment of wastewater of food industry. Reverse osmosis is an effective method for reducing the concentration of total dissolved solids (TDS) and many impurities found in water. Reverse osmosis membranes removes total dissolved solids, organic pollutants, viruses and bacteria[3].

The potato is a starchy, tuberous crop and around 15 gm of starch contain in 100 gm of potato. Starch consists of two types of molecules, linear amylose & branched amylopectin. Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight[7]. Starch is a high yield feedstock for ethanol production, but its hydrolysis is required to produce ethanol by fermentation. Starch was traditionally hydrolyzed by using acids, but today it is hydrolyzed by using enzymes.

The world bioethanol production has reached up to 51000 million with United States and Brazil getting top position and India getting fourth position [5]. Ethanol is produced by fermentation of sugar based raw-material such as corn, potato and wheat etc. Bio-ethanol must be anhydrous, if it is used as a fuel. For dehydration of ethanol conventional purification process such as distillation is commonly used. Alcohol content of the distillation product is limited to 95vol-% due to the formation of a water-ethanol azeotrope. So distillation is costly and very energy-intensive process[4]. Pervaporation is combination of membrane permeation and evaporation, and it can be used for separation of ethanol and water mixture. Ethanol concentration of 99% can be obtained by using energy efficient pervaporation process[9].

The main objective of this study is to find sustainable technique for the treatment of potato processing wastewater in order to minimize the water consumption and to utilize the solid waste such as starch, so that the potato processing industry is characterized as a clean industry.

2. EXPERIMENTAL:

2.1 Pretreatment of Raw Materials:

Wastewater was collected from Raghuveer Foods Industry, Amravati (M.S.). In potato chips industry, the wastewater obtained after cutting and soaking process was used for further experimentation. In the first stage of experiment, the water was filtered through 0.2 micron size cloth to remove macro size potato pieces. The alum was added into the filtered water to remove insoluble starch from water by sedimentation. The settled starch was separated from water and used further for the synthesis of bioethanol. The raw water after sedimentation was send to the Reverse Osmosis (RO) system for further purification.

2.2 Reverse Osmosis Unit:

Reverse osmosis unit is used for purification of water and recovery of starch from potato processing wastewater. Reverse osmosis equipment consisted of a feed tank, a high pressure feed pump, a permeate flow-meter and a pressure control system. The plant was equipped with a spiral-wound membrane module (ployether-sulphone membrane of pore size 0.0001µm), salt rejection minimum 99.0%, nominal membrane area 1.85m^2, pressure operating range 0-40Kg/cm^2, temperature operating range 25-40°C, pH operating range 3–10).

Figure 1. Reverse Osmosis Unit

2.3 Enzymatic Hydrolysis of Starch:

Starch powder of 10 gm was mixed with 100mL of distilled water. Now starch slurry was heated at 63°C for 15min. This process is called gelatinization. Starch hydrolysis was carried out using enzymes (α-amylase, Glucoamylase) in two steps. Alpha-amylase enzyme was dosed to potato starch solution and the solution was further heated in water bath at 63-65°C for 3 hrs. Alpha-amylase is used to hydrolyze α-1, 4 glycosidic bonds of starch and starch derivatives into soluble dextrin and oligosaccharides. This process is called liquefaction. After that gluco-amylase enzyme was added to potato starch solution and the solution was heated in water bath at 90-92°C for 2 hrs. Glucoamylase is used to convert starch to glucose. This process is called saccharification.

2.4 Fermentation of Glucose:

After completion of enzymatic hydrolysis of starch, the glucose solution was sterilized in autoclave for 15min at 121°C and 15psig. The resulting solution was cooled and transferred to the fermentor where yeast was added. The yeast species Saccharomyces cerevisiae converts glucose to ethanol and carbondioxide. After fermentation, the clean sterile cotton cloth was used to filter the fermented solution from solid residue.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Yeast}} \underset{\text{Ethanol}}{2\,C_2H_5OH} + \underset{\text{Carbon dioxide}}{2\,CO_2}$$

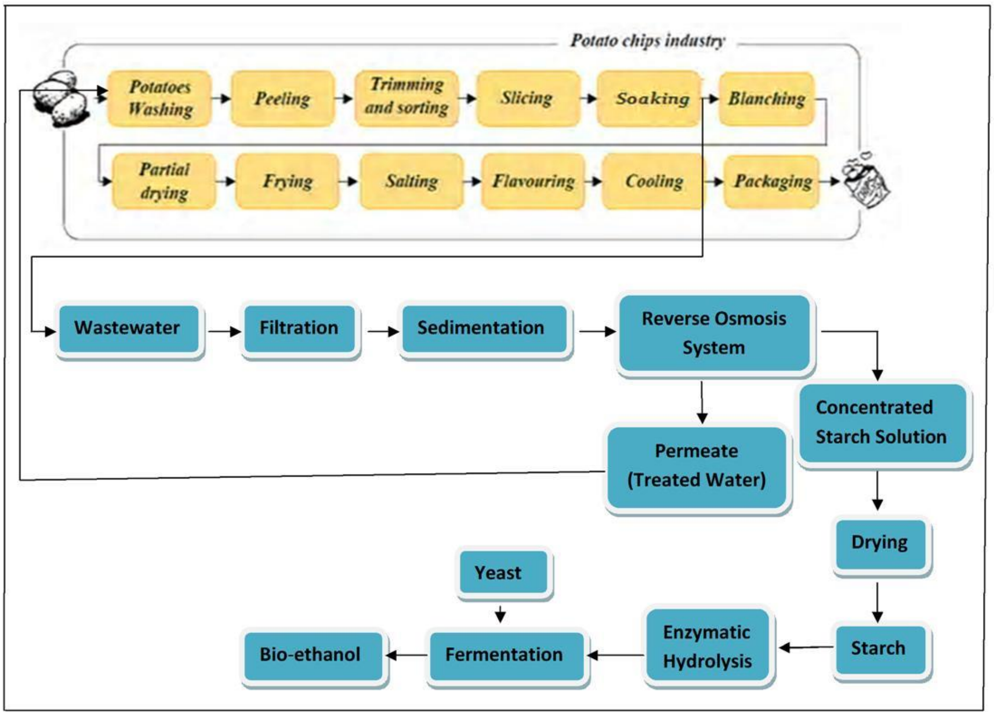

Figure 2. Flowchart of overall process

2.5 Analytical Techniques:

2.5.1 pH, TDS and Chemical oxygen demand (COD):

pH was determined by pH meter and TDS was measured by TDS meter. COD determines the amount of oxygen required to oxidize the organic matter in waste-water sample. COD was determined by Open Reflux Method.

2.5.2 Determination of Starch content, glucose content and ethanol content:

Starch is a polysaccharides polymer containing glucose monomers joined in 1,4-α-D-glucosidic linkages. Starch consists of two types of molecules, linear amylose(20-25%) and branched amylopectin(75-80%). The starch content of most foods cannot be determined directly because of complex glucosidic linkages. To breakdown the glucosidic linkages of starch, enzymes are added to the starch solution. Starch was hydrolyzed into glucose using enzymes and starch content was calculated from the glucose concentration.

Glucose content was determined by using spectrophotometer. 3mL of DNS reagent was added to 3mL of glucose sample in a test tube. The solution was heated in water bath for 5-15 min at 90°C until the red-brown color appeared. Then, 1 ml of a 40% potassium sodium tartrate solution was added to the heated solution to stabilize the color. After cooling solution to room temperature, the absorbance values of the reducing sugar was measured using spectrophotometer at 575 nm. Compare its absorbance value with standard once.

Ethanol content was determined by using spectrophotometer. Take 2ml of ethanol sample in test tube and add 2ml of potassium dichromate reagent solution then add 1ml of s–Diphenyl carbazide solution.

Mix the contents and the solution was then heated in water bath for 5-15 min at 90°C until the red-brown color appeared. Then, 1 ml of a 40% potassium sodium tartrate solution was added to the heated solution stabilize the color. After cooling solution to room temperature, the absorbance values of the reducing sugar was measured using spectrophotometer at 575 nm. Compare its absorbance value with standard once.

3. RESULT & DISCUSSION

The wastewater used for experimental work was collected from potato chips industry. The wastewater was obtained after cutting and soaking process, so this water contains low microbial charge.

3.1 Analysis of potato processing wastewater

Analysis of wastewater was carried out by measuring various parameters such as pH, starch, chemical (COD) oxygen demand and total dissolved solids (TDS) is shown in table1. The analysis of data in table1 reveals that potato processing wastewater contains higher chemical oxygen demand (COD) and total dissolved solids (TDS).

Table 1. Analysis of wastewater from potato processing industry

Sr. No.	Parameter	Values
1	pH	6.54
2	Starch	1.5%
3	TDS	820 mg/L
4	COD	7230 mg/L

Before treating wastewater using Reverse Osmosis system pretreatment is necessary. In the first stage, the wastewater was filtered through 0.2micron size cloth to remove coarse solid (macro size potato pieces). After filtration, alum was added to the filtered water to remove insoluble starch from water by sedimentation. Using sedimentation process 94% starch was settle-down and the 321gm of starch was recovered from 23liters of wastewater. The settled starch was air dried and used further for production of bioethanol. The wastewater obtained after sedimentation process was send to Reverse Osmosis (RO) system for further treatment of water.

3.2 Analysis of water from RO system

Purification of wastewater from potato industry was done by using reverse osmosis system. In RO system, different runs were carried out by varying inlet membrane pressure using 23liters of feed water. Effect of inlet membrane pressure on various parameters such as permeate flow rate, reject flow rate, volume of permeate and volume of reject have been observed.

Table 2. Effect of inlet membrane pressure on various parameter of RO system

Run	Feed Volume	Inlet membrane pressure	Outlet membrane pressure	Trans-membrane pressure	Permeate flow rate	Reject flow rate	Volume of permeate	Volume of reject
RO	Liter	Kg/cm^2	Kg/cm^2	Kg/cm^2	LPM	LPM	Liter	Liter
RO_1	23	5	1	3	0.5	16.5	14.5	8.5
RO_2	23	7	4	5.5	1	12	18	5
RO_3	23	10	7	8.5	1.7	5.5	20	3

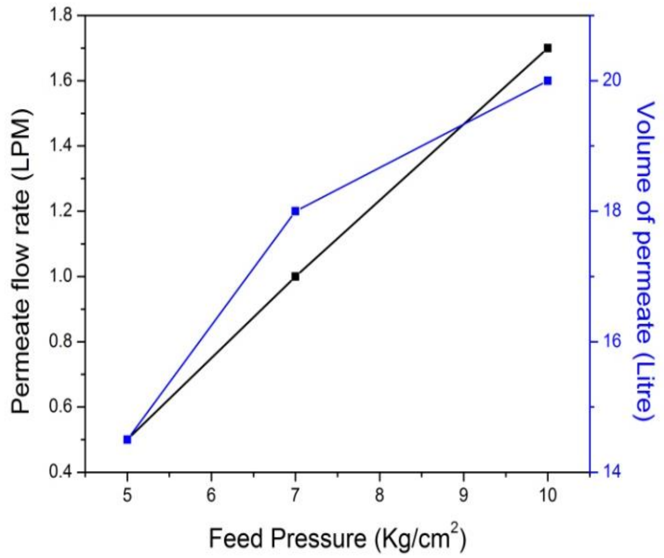

Figure 3: Effect of feed pressure on permeate flow rate and volume of permeate

Permeate flow rate and permeate volume increases as inlet membrane pressure increases due to increase in pressure gradient were observed in **Figure 3**. For feed pressure of 5 Kg/cm^2 and 7 Kg/cm^2, permeate flow rate and volume of permeate was low whereas for 10 Kg/cm^2 feed pressure, permeate flow rate increases satisfactorily up to 1.7 LPM and volume of permeate was appreciable for the treatment of potato processing wastewater.

3.2.1 Analysis of permeate water from RO system

Parameters such as total dissolved solid (TDS) and chemical oxygen demand (COD were calculated at each run of RO system in permeate water. It was observed that in **Figure 4,** total dissolved solid (TDS) rejection and chemical oxygen demand (COD) rejection increases as feed pressure increases**.** As a feed pressure increases, more dissolved and organic substances get rejected from permeate water. Hence total dissolved solid (TDS) rejection rate and chemical oxygen demand (COD) rejection rate increases as a feed pressure increases. The optimum value of transmembrane pressure was 8.5 kg/cm^2 where feed pressure was 10 kg/cm^2 shows higher rejection of dissolved solid and higher rejection of organic substance as compared other values of feed pressure that we have applied in our experiment. At optimum feed pressure, chemical oxygen demand (COD) rejection rate was 96.42% and value of COD in permeate water was 258 mg/L. The resulted value of COD in purified water is close to national wastewater discharge limits.

Table 3. Analysis of permeate water from RO system

Sr. No.	Run	Feed Pressure (Kg/cm^2)	TDS (mg/L)	Rejection of TDS (in %)	COD (mg/L)	Rejection of COD (in %)
1	RO_1	5	121	85.25 %	985	87.37%
2	RO_2	7	83	89.88%	671	91.72%
3	RO_3	10	39	95.25%	258	96.42%

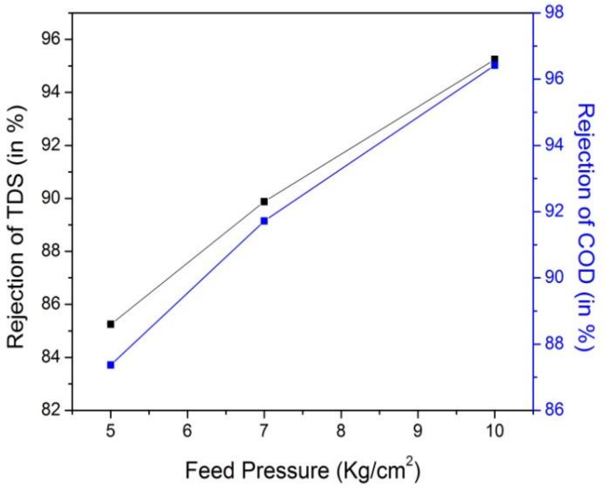

Figure4. Effect of feed pressure on %rejection of TDS and %rejection of COD

3.2.2 Analysis of concentrate water from RO system

Analysis of concentrate water was done by calculating the parameters such as Total dissolved solid (TDS) and recovery of starch in concentrate RO water. Feed pressure of 5 kg/cm^2 where transmembrane pressure was 3 kg/cm^2 shows only recovery of 0.32% starch. Dissolved solid molecule rejection rate increases as we increase the feed pressure and hence starch recovery rate increases. The optimum transmembrane pressure for higher rejection of dissolved solid and higher recovery of starch was 8.5 Kg/cm^2. At this optimum transmembrane pressure where feed pressure was 10 kg/cm^2 shows recovery of 0.72% starch in retained side RO water.

Table 4. Analysis of concentrate water from RO system

Sr. No.	Run	Feed Pressure (Kg/cm^2)	TDS (mg/L)	Recovery of Starch (%w/v)
1	RO_1	5	960	0.32

2	RO_2	7	1090	0.49
3	RO_3	10	1280	0.72

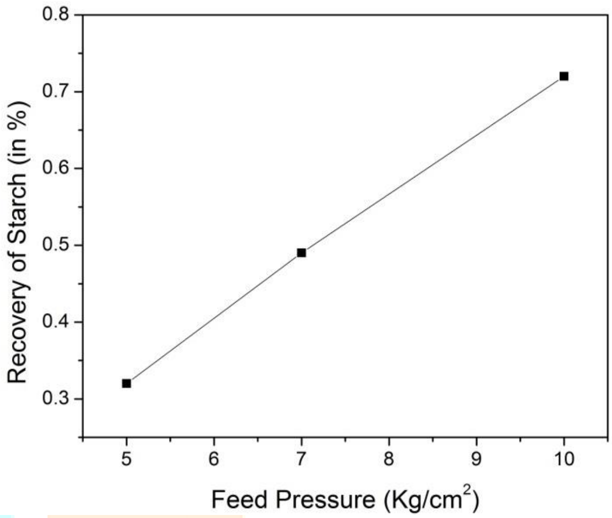

Figure 5. Effect of feed pressure on recovery of starch

Higher rejection of dissolved solid, higher rejection of chemical oxygen demand(COD) and higher recovery of starch in raw potato processing wastewater was observed at 10 kg/cm^2 feed pressure. Thus the optimum feed pressure for treatment of potato processing wastewater was 10 kg/cm^2 using polyethersulphone reverse osmosis membrane.

3.3 Hydrolysis of starch for glucose production

Enzymatic hydrolysis of starch was done for converting the starch into glucose. Suitable starch slurry concentration is required for getting the highest production of glucose. Therefore, different potato starch slurry (5%, 10%, 15%, 20%) was prepared in distilled water.

Table 5. Concentration of potato starch solution for optimum glucose production

Sr. No.	Starch concentration (%w/v)	Glucose concentration (%w/v)	% Conversion
1	5	4.5	90
2	10	9	90
3	15	12.5	83.3
4	20	15.25	76.25

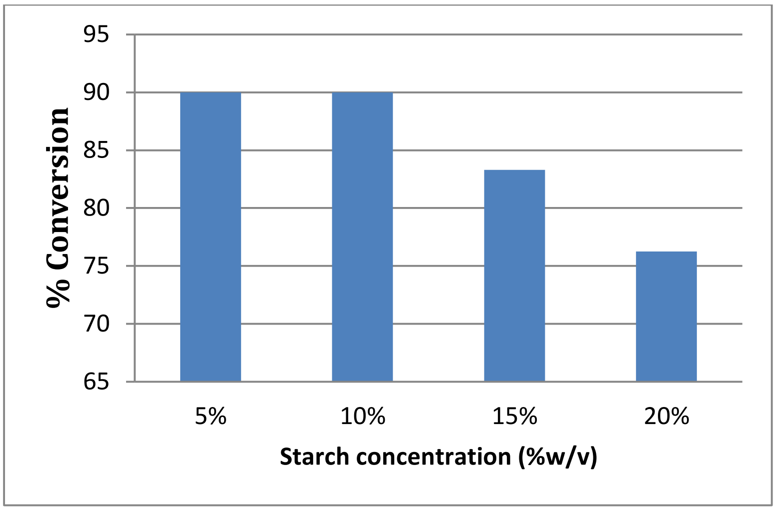

Figure 6. %Conversion of glucose from starch solution

Highest conversion of glucose was found up to 10%potato starch solution**(Figure6).** Increase of potato starch concentration result in less formation of free glucose because of incomplete saccharification of starch. Low concentration of glucose provided a low yield of bioethanol. Hence it is beneficial to use 10% starch solution as a feedstock for high scale production of biofuel.

3.4 Fermentation of glucose for ethanol production

Fermentation was carried out at anaerobic condition using Saccharomyces cerevisiae (baker's yeast). When yeast is submitted to anaerobic conditions, its changes the simple sugars into ethanol and carbon dioxide. Abul Kalam Azad et.al was observed that optimum pH and temperature for cell growth of yeast (Saccharomyces cerevisiae) were 6.0 and 31°C respectively. Sufficient fermentation time is required for production of bioethanol by yeast. Abul Kalam Azad et.al was found that 6-days incubation period is good for optimum production of bioethanol. Long incubation period reduced the production of bioethanol because potato contains starch, protein and fat. Protein and fat energy helps the yeast to convert bioethanol into other products and resulting a low formation of ethanol was observed after six days of incubation period.

The percentage of bioethanol production was measured at 24hrs interval for 6 days at different potato starch solution by anaerobic fermentation using Saccharomyces cerevisiae **(Table 2)**. Bioethanol production increases as a fermentation period increase is indicated in **Figure 7**. From this study, we found that there was rapid increment of ethanol concentration from 0 to 3 days of fermentation period because initially intense maximum glucose was utilized by yeast cells to produce bioethanol. However from 4 to 6 days of fermentation period, there was slight increment of the bioethanol production. Theoretically ethanol content is 4.9% but actual we got 4.7% of ethanol from 9%(w/v) of glucose solution because total glucose was not used in fermentation.

Table 6. Percentage of bioethanol production from different concentration of potato starch solution for six days of fermentation period

Production of ethanol (%v/v)						
Days → / Potato Starch Solution	1	2	3	4	5	6
5%	0.31	0.73	1.4	1.8	2.1	2.3
10%	0.65	1.5	2.7	3.9	4.3	4.7
15%	0.87	2.1	3.8	5.5	6	6.5
20%	1.1	2.6	4.8	6.8	7.5	8.2

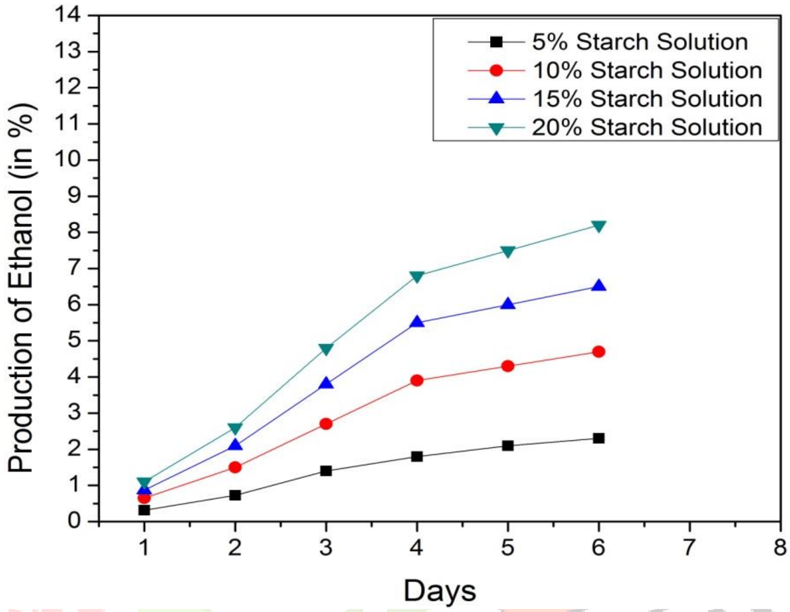

Figure7. Variation in ethanol production with change in starch solution concentration for six days of fermentation period.

4. CONCLUSION:

Optimum feed pressure for treatment of potato processing wastewater was 10 kg/cm^2 using polyethersulphone reverse osmosis membrane. Optimum feed pressure where the transmembrane pressure was 8.5 Kg/cm^2 shows rejection of 95.25% dissolved solid and 96.42% chemical oxygen demand and recovery of 0.72% starch.

Starch solution of 10% was found optimum for maximum conversion of bioethanol. Moreover, 4.7% of bioethanol was produced from 10% starch solution for six days of fermentation period using Saccharomyces cerevisiae (baker's yeast).

Water consumption in potato processing can be minimized by recycling the treated wastewater using reverse osmosis (RO) system. Moreover, the solid waste such as starch can be used for the synthesis of bioethanol so that potato processing industry can be characterized as a clean industry.

5. ACKNOWLEDGEMENT:

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