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USE OF STEAM-PEELED POTATO WASTE AS A BREWING ADJUNCT

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ABSTRACT

The use of steam-peeled potato waste as a brewing adjunct was investigated as a waste recovery technique for potato processing companies. Potato residue from Allen Canning Company in Siloam Springs, Arkansas, was used as a brewing adjunct in the production of 3 different styles of beer. The potato adjunct contributed no undesirable flavors or qualities to the finished beers at an adjunct useage of up to 27% (w/w). The amount of potassium and phosphorous was found to be double that of an equivalent commercial beer. A sensory evaluation using the 9-point Hedonic scale was conducted to test the overall acceptability of potato beer with 293 participants; the majority of participants rated the potato beer in the categories between "like" and "like extremely". Economic projections indicate that a significant cost-reduction can be made using this residue instead of rice as the adjunct. As a waste management technique, this process would be successful in processing all of the waste stream from the steam-peeling operation; the residual (brewers) solids from the brewing process could be used as a food additive or as an animal feed. The brewers solids were found to contain 18% crude protein and 29% neutral detergent fiber.

Keywords: potato waste, waste recovery, beverage alcohol, brewing adjunct, beer

INTRODUCTION

The food processing industry is a prime candidate for waste recovery technologies; an estimated ten billion pounds of potato waste alone is generated annually (Wann, 1990). Yet steam-peeled potato waste should not be considered a "waste" but rather a food-grade resource with a negative cost that can be used directly as an animal feed or processed into many human food products such as beer or snack items. Furthermore, this resource is a rich substrate for many different microbial fermentations which can transform the residue into a variety of products such as fuels, sweeteners, vitamins, and antibiotics.

The use of potato as an adjunct can be found throughout the history of beermaking; for example, *Schoenling Brewery* (United States) used potato as an adjunct (up to 30%) to compensate for the scarcity of malted grains during the Second World War (Phipps, 1993). Currently, the *Steven's Point Brewery* in Wisconsin is making a beer with potato called, of course, "Spud Beer" (Power, 1993). Potato residue from food processing industries has apparently not yet been tried as a brewing adjunct. To make the residue a food-grade resource the only process modification needed in a canning operation such as the one at Allen Canning Co. in Siloam Springs, Arkansas, is a longer pre-wash (Crocker, 1993). A disadvantage of using potato residue as an adjunct is that it has a much greater moisture content, being a slurry, than other adjuncts such as rice and corn grits, which could result in higher transportation costs. However, if breweries are situated relatively close to potato processing plants, the cost of transportation and storage of the potato residue can be minimized. Such a brewery could save considerably on the cost of the normal adjunct (see Results section for an estimate); and the canning company could save considerable cost in waste management.

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METHODS AND MATERIALS

The use of steam-peeled potato residue as a brewing adjunct was investigated in this research. The performance characteristics of this adjunct were examined by measuring brewing parameters in three different styles of beer (Dry Stout, Pale Ale, Wheat), and by determining the consumer acceptability of these beers by sensory evaluation. The potassium and phosphorous contents were compared to a commercial beer. The residual solids were measured for their animal feed value. An economic projection was made of possible savings.

Potato Residue Sample Collection and Preparation

The potato peel residue from the Allen Canning Company plant is generated from the processing of white potatoes into canned new potatoes. The potatoes are washed, steamed in a high pressure steam chamber for 30 to 60 seconds, and then sent to a scrubber (Magnusson) where the peel and approximately 30% of the potato are removed. The temperature of the residue ranges from 43 to 93 °C, has a neutral pH, and has the appearance and consistency of mashed potatoes (Crocker, 1993).

Potato peel slurry, at approximately 20% solids, was collected from the steam-peeling operation, and stored in sealed, plastic containers at -1.1 °C. During brewing, defrosting and gelatinization was ensured by boiling the residue in water and using this solution to help raise the temperature from the protein rest temperatures to starch conversion temperatures during mashing.

Fermentation Medium Preparation

Yeast cultures of *Saccharomyces cerevisiae* (Arauner, West Germany) were stored in 500 mL sterile flasks at 7.2 °C. Inoculation volume averaged 1% (v/v).

Mashing was carried out in a 40 L insulated container. The cracked grains, potato residue, and water were slowly heated and kept at 50.0 °C for 30 minutes for the protein rest. The mash was then raised and sustained at 66.1 °C for 1 to 2 hours to complete the starch hydrolysis. The starch end-point was tested visually by the iodine test: a 140 g sub-sample of the extract was removed and placed in a crucible, and a few drops of tincture of iodine was added and color change observed.

Lautering was achieved using two stacked 19 L food-grade plastic buckets; the inner bucket had hundreds of 3 mm holes drilled in its bottom and the outer was fitted with a valve at the bottom. The mash was poured from the insulated container into this false-bottom straining system; the grains formed a filter bed, and the filtered extract flowed into the boiling kettle. After the extract drained, 11-19 L of sparge water at 76.6 °C were used to rinse the residual sugars from the grains, terminate the enzyme activity, and make up the final volume of wort.

Boiling was carried out in a 22.7 L steel pot over gas flame for 1 to 1.5 hours, depending upon the formula. Irish moss (1 g) was added to aid in coagulation and the precipitation of proteins. Gypsum (4-8 g) was added to adjust the pH to the proper level of the beer style (Papazian, 1991). After boiling, the wort was passed through a chiller and funneled into a sterilized 19 L (5 gallon) glass carboy to achieve a temperature at or below 32 °C.

Fermentation Procedure

After the density of the wort was measured by hydrometer at 15.6 °C, its calibration standard, the wort was inoculated with 240 ml of yeast culture. The glass carboys were sealed with #7 rubber stoppers and water locks to maintain an anaerobic environment. Brewing time varied between 2 to 6 days. The completion of the fermentation was determined by a constant reading of the hydrometer over a 3 day period. The beer was then racked (transferred) to a new carboy. Finally, the beer was primed with 180 mL of corn sugar for carbonation, bottled, and allowed to age a minimum of 3 weeks before use in sensory evaluations.

Brewing Formulas

Dry Stout Formula: 3.2 kg British 2-row malted barley (Muton and Fison)
0.9 kg potato residue (Allen Canning Co.)
0.4 kg roasted barley (Klagges)
42 g hop pellets (Northern Brewers)

Pale Ale Formula: 2.3 kg British 2-row malt (Muton and Fison)
0.9 kg potato residue (Allen Canning Co.)
0.2 kg crystal malt (Klagges)
42 g hop pellets (Cascade)

Wheat (Weizen) Formula: 2.3 kg malted wheat (Klagges)
0.9 kg British 2-row malt (Muton and Fison)
0.5 kg potato residue (Allen Canning Co.)
42 g hop pellets (Cascade)

Measuring the Hydrolysis

The method used to measure the mashing procedure was the **Degrees extract** method (used by the British brewing industry) (Power, 1993). This method compares the density of extract from a particular mash to a recognized standard. This density standard is given in degrees extract per kilogram (degree specific gravity x L / kg), which represents the maximum yield of extract possible from a given weight (kg) of ingredient, volumetrically adjusted, and is listed in Table 1.

Table 1. Degrees Extract per Pound for Brewing Ingredients Used

Brewing Ingredient	**Degrees Extract per Kilogram** deg x L / kg
Two-row malt	292 +/- 1
crystal malt	200
wheat malt	317
corn, rice flake	334
roasted barley	200

(Line, 1974; Miller, 1991)

By multiplying the weight (kg) of each ingredient by its respective degrees extract per kilogram (degree x L / kg) and then summing all of these degrees extract, a total optimum degrees extract (degree x L) for that brew is calculated. The ingredients are then prepared and mashed and the specific gravity of the extract is measured. The actual degrees extract (degree x L) is then calculated by multiplying the specific gravity reading (degree) by the final volume (L). The extent of hydrolysis (%) of the ingredients is thus the ratio of the actual yield of extract over the optimum yield of extract multiplied by 100. A calculation of 100% would mean that the measured mash contained the maximum amount of fermentable sugars obtainable by industry's standards.

Measurement of Degrees of Extract Value for Potato Residue

Since no values of degrees extract exist for potato residue, the value was calculated. Samples of potato residue were pulverized in distilled water, brought to a boil, and then simmered on a magnetic stirrer/heater for 20 minutes to ensure liquefaction. The temperature of the solution was then lowered to 66.1 °C and 5 grams of amylase (Wines, Inc.) were added, and stirred for 45 minutes for saccharification. The solution was then cooled to 15.5 °C, the density measured by a hydrometer, and the degrees of extract calculated.

Ethanol Content

The ethanol concentration (% w/w) was measured by gas chromatography with a flame ionization detector and a Porapak Q column at 170 °C. Normal propyl alcohol was used as the internal standard.

Crude Protein and Fiber Analyses

Both the potato residue and the residual solids of the Dry Stout #2 were analyzed for crude protein and crude fiber to determine their value as animal feed. Crude protein was measured by the Kjeldahl content method using a Kjeltec Analyzer. Crude fiber was measured using the neutral detergent fiber (NDF) analysis.

Total Potassium and Total Phosphorous

Samples of two beers were analyzed; one was the Dry stout #2 and the other was the commercial beer *Lowenbrau Dark Special* (Miller Brewing Co.). Total potassium was measured after a nitric-sulfuric acid digest using atomic absorption spectrophotometry. Total phosphorous, measured as phosphate, was measured calorimetrically using the ascorbic acid method.

Sensory Evaluation

To determine the affective status, i.e., how well the beer was liked by consumers, an acceptance test was performed on the finished brews. The 9-point Hedonic scale was used. The Hedonic scale ranges from 1, labeled "dislike extremely", through 5, labeled "neutral", to 9, labeled "like extremely" (Heilgaard, 1991). The participants were given a two-ounce serving of each of the 3 experimental brews and were asked to rate the beers using this criteria. Each beer sample was given a random 3-digit identification.

RESULTS AND DISCUSSION

Determination of Degrees of Extract Value for Potato Residue

The maximum yield of extract from potato residue was found to be approximately 73 degrees extract per kilogram, as shown in Table 2. This value is lower than the values for the other brewing ingredients listed in Table 1 because the potato residue is in slurry form (20% solids) and the other ingredients are dehydrated. After gelatinization of ingredients, potato rivals rice and corn in starch content; cooked potato has 18.5% total carbohydrate (w/w), while cooked rice has 28.0% and corn has 15.6% (Woolfe, 1987).

Table 2. Determination of Degrees Extract Value for Potato Residue

Rep. #	Weight Raw Residue g +/- 0.01	Total Volume mL +/-1	Degrees Specific Gravity deg +/-0.5	Degree Extract Per Kilogram deg x L / kg
1	366.07	1143	23.0	71.81
2	300.88	880	24.0	70.19
3	327.49	1014	23.5	72.76
4	454.03	3835	9.5	80.24
5	227.00	1894	8.5	70.92
			Average	73.18

Optimum Degrees of Extract

Table 3. Optimum Yield of Extract

Beer Style	Ingredient Amount kg	Degree Extract Per Pound deg x L / kg	Total Degrees Extract deg x L
Dry stout	3.2 kg two-row malt 0.9 kg potato residue 0.4 kg roasted barley	292 73 200	934.0 65.7 80.0
		Total	1079.7
Pale Ale	2.3 kg two-row malt 0.9 kg potato residue 0.2 kg crystal malt	292 73 200	671.6 65.7 40.0
		Total	777.3
Wheat (Weizen)	2.3 kg wheat malt 0.9 kg two-row malt 0.4 kg potato residue	317 292 73	729.1 262.8 29.2
		Total	1021.1

Efficiency of Hydrolysis

In Table 4 the actual degrees of extract obtained in the wort is compared (as a percent) to the optimum degrees of extract calculated in Table 3. This ratio is used as a measure of the extent of hydrolysis during mashing for each brew.

The starch conversion efficiencies were used to determine the proper concentration of potato adjunct in a beer style and to measure the extent of hydrolysis. It was observed that an adjunct use of up to 27 % could be used for light and amber beers such as our *pale ale* and *wheat* without producing off-flavors or problems with starch hazing. In the dark beers such as the *dry stout*, up to 20 % adjunct use was successful before the beer began to be diluted with the potato, resulting in a loss of body (palate fullness). The extent of hydrolysis increased and finally exceeded 90%

with successive replications of a beer style. This increase in efficiency is due to the refinement of the brewing process as the research progressed. In general, the lower efficiencies of the different brews tended to make a lighter-bodied version of the beer style but did not seem to interfere with the appreciation of the final product. Optimum mashing efficiency is important economically, however, to ensure that the ingredients are being fully utilized.

Table 4. Efficiency of Hydrolysis

Beer Style Brew #	**Degrees Specific Gravity** deg +/-0.5	**Final Volume** L +/-0.1	**Actual Degrees Extract** deg x L	**Optimum Degrees Extract** deg x L	**Percent Conver-sion** %
Dry Stout #1	34.0	19.8	673.2	1079.7	62
#2	52.5	18.9	992.3	1079.7	92
Pale Ale #1	26.0	19.8	514.8	777.3	66
#2	27.5	19.8	544.5	777.3	70
#3	25.5	20.8	530.4	777.3	68
#4	29.0	19.8	574.2	777.3	74
#5	36.0	18.9	680.4	777.3	88
#6	34.0	18.9	642.6	777.3	83
#7	35.0	18.9	661.5	777.3	85
#8	33.0	19.8	653.4	777.3	84
#9	36.0	19.8	712.8	777.3	92
Wheat #1	30.5	19.8	603.9	1021.1	60
#2	36.0	18.9	680.4	1021.1	67

Alcohol Content

Table 5. Alcohol Content

Beer Style	Pale Ale #1	#2	#3	#4	#5	#6	#7	#8	#9
% EtOH	2.56	2.53	2.11	2.58	3.19	2.90	2.49	2.92	3.07
Beer Style	Dry Stout #1	#2		Wheat #1	#2				
% EtOH	2.67	3.82		2.37	3.06				

Results of Crude Protein and Fiber Analyses

Table 6 shows that the brewing solids of Dry Stout #2 contained 18% crude protein, exceeding corn (9%) and wheat (14%) in protein (Kellog, 1993).

Table 6. Crude Protein Analysis Results

Sample Type	Sample Weight g	H_2SO_4 g	% Nitrogen %	% Protein %
potato residue	2.0003 2.0001 2.0007	21.19 21.93 21.31	2.167 2.243 2.179	13.54 14.02 13.62
			Average	13.73
brewers solids	0.5002 0.5008 0.5001	6.929 7.207 6.779	2.833 2.944 2.733	17.71 18.40 17.33
			Average	17.81

Table 7 shows that the brewing solids tested have a fiber content between that of corn and alfalfa (the average neutral detergent fiber content of corn is 10% and of alfalfa hay is 45%) (Kellog, 1993).

Table 7. Neutral Detergent Fiber Content Comparison Results

Sample Type	Sample Weight g	Crucible Weight g	Crucible + Sample Weight g	% Neutral Detergent Fiber %
potato waste	0.5005 0.5004 0.5007	35.1652 34.9978 33.7724	35.2574 34.1146 33.8642	18.43 23.34 (omit) 18.33
			Average	18.38
brewers solids	0.5000 0.5006 0.5007	34.4777 35.4742 34.8896	34.6150 35.6224 35.0348	27.46 29.60 29.00
			Average	28.69

The residual (brewers) solids are obviously an excellent feed for animals. The solids are of food grade quality, however, and can be used as such; for example, *Wiedman's Old Fort Brewpub*, in Fort Smith, Arkansas, uses their brewers solids to replace up to 40% of the flour used in making their bread and pizza dough, giving these baked goods a unique, hardy character and a marketing edge (Wiedman, 1993).

Total Potassium and Phosphorous

The experimental beer, Dry Stout #2, contained more than double the amount of potassium and phosphate than the commercial equivalent beer, as shown in Table 8.

Table 8. Total Potassium and Phosphorous Content Comparison Results

Sample Type	**Total Potassium** mg/L +/-1	**Total Phosphorous as Phosphate** mg/L +/-1
Lowenbrau	408	153
Dry Stout #2	930	352

Sensory Evaluation Results

The results of the sensory evaluations of the three beer styles are shown in Table 9.

Table 9. Results of the Sensory Evaluation

Beer Style	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Sample Size**
Pale Ale	6	4	5	9	13	21	29	30	33	150
Dry Stout	1	9	4	5	0	7	9	7	14	56
Wheat	1	1	2	3	2	6	21	28	23	87
Total	8	14	11	17	15	34	59	65	70	293

To determine if the majority of participants liked the beer, the null hypothesis that the distribution of participants that liked the beer (categories 7 through 9) is not significantly greater than one half of the total number of participants was tested using equations 1 and 2 (McNew, 1994):

H_o: $P_o = 0.5$ (categories 7 through 9 are not significantly greater than 0.5)
H_i: $P_o \neq 0.5$ (categories 7 through 9 are significantly greater than 0.5)

$$P^{\wedge} = (59 + 65 + 70) / 293 = 0.662 \quad (1)$$

$$z^{\wedge} = (P^{\wedge} - P_o) / \{[\text{sq rt } (P_o \times (1 - P_o))] / n\} = 5.548 \quad (2)$$

At the 99% confidence level (alpha = 0.01), z = 1.00 (with 194 and 293 degrees of freedom) (McNew, 1994). Since $z^{\wedge}$ is greater than 1.00, H_o is rejected and H_i is accepted. Thus, categories 7 through 9 are significantly greater than one half. **Thus, over 50% of the participants rated the overall acceptability in the range of 7 - "like" to 9 - "like extremely".**

Economic Projections

To estimate the cost reduction of using potato residue instead of rice as the adjunct for brewing, the following calculations were made (Equation 3):

Given that the price of brewers' rice (brokens) is $ 0.13 per kg ($5.80 per 100 lbs) (Mines, 1993), that 1 kg of rice converts to 0.82 kg rice extract (Phipps, 1993), an average beer contains 13.7 kg of extract per barrel (117 L) (Phipps, 1993), and an adjunct use of 30%, then the price of the rice adjunct per liter would be:

($0.13 / kg rice) x (1 kg rice / 0.82 kg rice ext.) x
(0.3 kg rice ext. / kg total ext.) x (13.7 kg total ext. / 117 L beer)
= $0.006 / L ($0.02 / gal beer)

(3)

Assuming that potato residue costs nothing to use an adjunct, **a brewery can save approximately 2 cents per gallon** of this beer if potato residue is substitued for rice as the adjunct.

This estimate could be larger if the cost of the energy used to gelatinize a normal adjunct (including washing and pulverizing), which the potato residue does not need, is included. Furthermore, since the potato slurry is already preheated to 93 °C, the energy normally required to raise the grist to mashing temperatures could also be reduced considerably.

CONCLUSION

This research demonstrates that using the potato residue from a canning company to brew beer is feasible and provides an alternative to current waste management techniques. The potato residue performs as well as other adjuncts without their cost; a brewery could save considerable energy and money if it were sufficiently close to a food processing operation. This research examines only one of the many possible uses of this resource, and demonstrates that applying ecological precepts to engineering challenges will produce solutions that are practical, profitable, and refreshing.

REFERENCES

1. Crocker, Tom. 1992-1993. Personal correspondence. Plant Manager, Allen Canning Company, Siloam Springs, Arkansas.

2. Heilgaard, M., Civille, G., and Carr, B. 1991. Sensory evaluation techniques. CRC Press, Inc., Boca Raton, Florida. 452 p.

3. Kellog, D. 1993. Personal correspondence. Professor of Animal Science, University of Arkansas, Fayetteville, Arkansas.

4. McNew, R. 1994. Personal correspondence. Professor of Agricultural Statistics, University of Arkansas, Fayetteville, Arkansas.

5. Miller, Dave. 1991. The complete handbook of home brewing. Garden Way Publishing, Inc., New York, New York. 311 p.

6. Mines, Daniel. 1993. Personal correspondence. Marketing division, Riceland Foods, Inc., Pine Bluff, Arkansas.

7. Papazian, Charlie. 1991. The new complete joy of home brewing. Avon Books, New York, New York. 235 p.

8. Phipps, Mark. 1993. Personal correspondence. Brew Master and Manager of Product Development at ENERFAB, Inc., Cincinatti, Ohio.

9. Power, J. 1993. Personal correspondence. Professor at the Siebel Institute, Chicago, Illinois.

10. Wann, David. 1990. Biologic. Johnson Books, Boulder, Colorado. 367 p.

11. Wiedman, Terry. 1993. Personal correspondence. Co-owner and chef, Wiedman's Old Fort Brewpub, Fort Smith, Arkansas.

12. Woolfe, Jennifer. 1987. The potato in the human diet. International Potato Center, Cambridge University Press, Cambridge, U.K. 331 p.