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Expression of Alfalfa Juice

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A double-roll laboratory-scale press was developed for the expression of juice from alfalfa or other vegetation. It has a wet feed capacity of approximately 3 kg/h. Some preliminary studies were performed with the press. Cooling the forage before processing had no effect on the expression of alfalfa juice while heating generally had detrimental effects. Maceration before pressing proved advantageous, but the importance of the addition of water to forage before pressing was not conclusively shown.

The fractionation of green crops is theoretically attractive. Although high yields per hectare of crude protein and dry matter can be obtained from green crops, the crude protein is used inefficiently by ruminant animals. In addition to this, the whole crop cannot be used efficiently by nonruminants and humans (Jones, 1977).

It is possible to mechanically extract protein for nonruminant animal and human consumption with the remaining residue being used by ruminants. The processes range from the extraction of a low protein with the pressed crop still being the final product to exhaustive extraction with leaf protein concentrate for human consumption being the final product (Jones, 1977).

In order for green crop fractionation to be widely adopted, it must be possible to inexpensively express plant juice at reasonably high rates. This requires a knowledge of the concepts of cell rupture and juice expression. The nature and requirements of these processes have been investigated. Jones (1977) has compiled information on the principles of green crop fractionation and has identified some areas where additional research is needed.

While the largest differences in protein yield can be attributed to varietal differences for the leaves involved, substantial yield differences appear to be due to differences in growth and harvesting conditions, processing conditions prior to expression, and expression conditions. Juice protein yield has been empirically correlated with various processing-, harvest-, and growth-related factors.

A wide variety of factors influence juice and protein recovery during juice expression from macerated alfalfa leaves. These include (1) cell rupture, (2) fragmentation of protein-containing cell organelles, particularly chloroplasts, (3) pressing rates during expression, (4) press cake mass per unit of outflow area, (5) juice viscosity, (6) blinding of the expression outflow medium, (7) organelle and juice entrapment within pores which are blocked during the compaction that accompanies expression, and (8) soluble protein coagulation and chloroplast flocculation prior to and during expression. Schwartzberg et al. (1977) indicated that all of the above factors are important.

Roughly 88–95% of the protein-containing cells in alfalfa are opened by vigorous maceration, but, because of press cake blinding, only 65–75% of the mobile protein content (46–53% of the total protein content for alfalfa, 80% of whose protein is mobile) can be recovered by simple, single-stage pressing. However, almost all of the remaining mobile protein in the open cells can be recovered by multistage addition of water and expression following the first pressing. The protein concentration reductions caused by such rewetting and expression can be minimized by carrying out the process in a countercurrent fashion. Approximately 20% of the protein in the alfalfa appeared to be immobile and susceptible to recovery only by chem-

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ical or enzymatic treatment (Schwartzberg et al., 1977).

On the basis of pilot plant data, juice protein yields for alfalfa vary widely. It, therefore, appears that the immobile protein content of alfalfa may also vary widely. Most frequently 30–40% of the alfalfa crude protein is immobile, but occasionally (e.g., for senescent alfalfa or alfalfa which has been exposed to temperatures in excess of 30 °C) up to 60% of the crude protein may be immobile.

Because alfalfa protein progressively precipitates as temperature is increased and pH is decreased, it is likely that some immobilization occurs due to protein precipitation within the alfalfa prior to processing. This is because alfalfa undergoes spontaneous heating and juice pH reduction after harvesting. When alfalfa was cooled rapidly after harvesting, protein immobilization due to spontaneous heating may have been eliminated (Schwartzberg et al., 1977).

Addy et al. (1975) demonstrated the significance of various structural and mechanical factors in process design for leaf protein production. From a mechanical perspective, the types of force, as well as loading rates and shear gaps, have been shown to influence rupture characteristics. Dynamic compression was more effective than shearing as a rupturing process. If the drawbacks of vibration, heat, and noise can be minimized, it would be potentially superior to present commerical processes. They also indicated that, in spite of the simplicity of the test methods, the evaluation of fundamental factors could be quite valuable in ultimate widescale commercialization of leaf protein.

Edwards et al. (1978) reported that grinding substantially increased the yield of leaf protein concentrate (LPC), dry matter extracted, crude protein extracted, crude protein recovered, and press cake dry matter content from fresh alfalfa dewatered in a twin-screw press. Average LPC yields of 15.2% (dry basis) can be obtained from ground alfalfa by using the twin-screw press. Grinding of wet, field-chopped alfalfa can be accomplished without clogging in existing commercial hammermills of appropriate design. The yield of LPC and other processing results can be predicted from a multiple linear regression equation if the appropriate raw material and processing parameters are known.

Koegel et al. (1973) found the degree of cell rupture in plant material to be mainly a function of the maximum pressure gradient to which the material was subjected and largely independent of the maximum pressure. The fiber of stems was much stronger than that of leaves, and the mixture of the two materials may facilitate the degree of cell rupture and the degree of protein extraction from the leaves and improve handling.

Cell rupture and juice expression should be carried out separately (Koegel et al., 1973). This makes the entire plant liquid available for flushing out the chloroplasts which tend to be released somewhat later in the rupturing process. The chloroplasts are a major source of protein in the expressed juice.

The objectives of this study were to evaluate the operation of a laboratory model press and to then determine the effects of heating, cooling, maceration, and addition of moisture before pressing on the expression of alfalfa juice with this press in order to develop a standard procedure for future studies on variables such as alfalfa maturity, cultivar, multiple cutting, and height of cut.

EXPERIMENTAL SECTION

Press. The portable laboratory model press developed for expressing juice from green forage is shown in Figure 1. Pressing is accomplished by two 8-cm diameter stainless steel rolls, 22 cm long, turning at 36 rpm with no clearance (the rolls are actually forced together). The roll surfaces were finished with a 0.13-mm depth straight knurl. The rolls are positively driven by a chain and sprocket drive and meshing gears on the end of the rolls. One roll is cleaned with a rotating brush while the other is cleaned with an adjustable metal scraper.

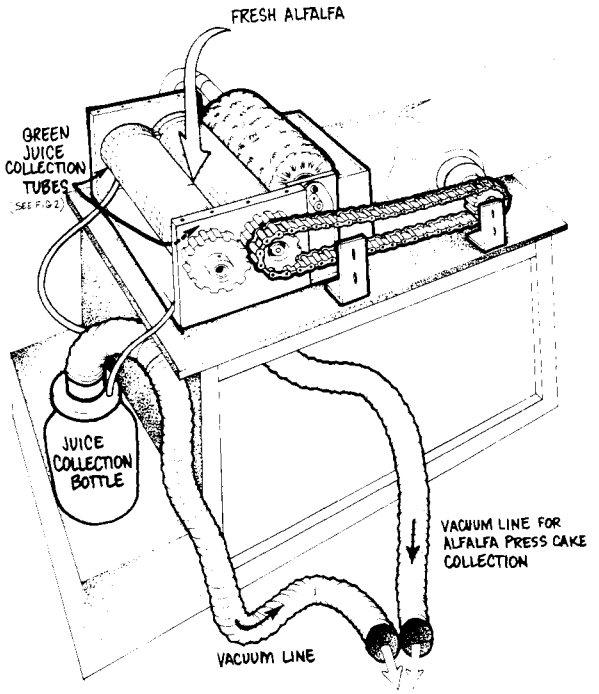

Figure 1. Schematic of the laboratory model press.

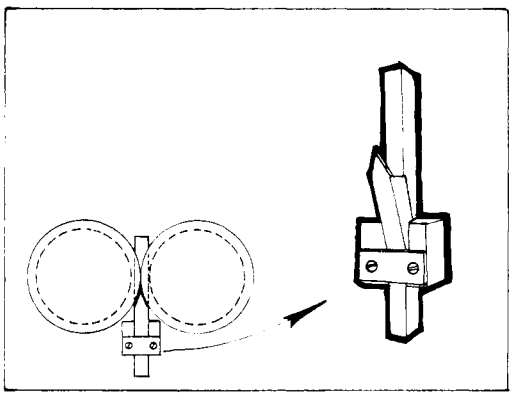

Figure 2. Diagram of the vacuum nozzle pickup unit for collection of green juice.

Because no clearance exists between the rolls, the juice extracted remains in the groove on top of the rolls and flows in both directions to the ends of the rolls. A vacuum pickup nozzle (Figure 2) is mounted in the groove between the rolls at both ends to draw off the green juice.

A hopper is attached below the rolls and a vacuum line removes the press cake (Figure 3). The simultaneous collection of the green juice and press cake is accomplished with the same vacuum system as diagrammed in Figure 1. The safety shielding and hopper are shown in Figure 4.

The unit has a capacity of 2.5–3 kg/h when powered by a $^1/_3$-hp gear reduction motor with a 48:1 ratio. The capacity is limited more by the diameter of the rolls and the amount of knurling than by the motor size. With the exception of the vacuum system, there is very little operating noise. As would be expected, there is considerable bearing wear because of the roll pressure. However, for

Table I. Effect of Forage Temperature on Constituent Contents and Yield of Pressed Alfalfa Cut on 7-31-78

		forage temperature, °C				
		7	25	35	50	60
dry matter content, %[a]	forage	19.9	21.5	21.4	21.8	22.2
	press juice	11.8	14.8	14.1	14.0	13.4
dry matter recovery, %	press cake	57.0	55.1	56.8	57.3	59.5
	chloroplast	19.0	19.5	20.0	21.1	20.4
	cytoplasm	17.8	19.8	16.5	16.4	15.2
protein content, %	forage	17.2	17.2	17.2	17.2	17.2
	press cake	10.4	10.0	11.0	11.4	13.9
	chloroplast	29.2	24.4	26.4	28.1	29.7
	cytoplasm	32.0	33.3	30.9	27.8	20.3
protein recovery, %	press cake	34.4	32.2	36.4	37.9	48.3
	chloroplast	32.3	23.6	30.7	34.5	35.3
	cytoplasm	33.2	38.4	29.8	26.5	18.0
carotene content, mg/kg	forage	217	205	202	187	185
	press cake	58	48	56	55	100
	chloroplast	630	514	429	326	477
	cytoplasm	76	159	107	55	9
carotene recovery, %	press cake	15.3	12.9	15.7	16.8	32.2
	chloroplast	55.1	49.0	42.5	36.7	34.8
	cytoplasm	6.2	15.3	8.8	4.8	0.7
xanthophyll content, mg/kg	forage	299	271	277	270	263
	press cake	75	75	90	93	146
	chloroplast	972	750	709	635	509
	cytoplasm	75	165	126	106	20
xanthophyll recovery, %	press cake	16.4	15.3	18.4	19.7	33.0
	chloroplast	61.7	54.1	51.2	49.6	39.5
	cytoplasm	4.4	12.0	7.5	6.5	1.1

[a] Wet basis; all other values are on a dry basis.

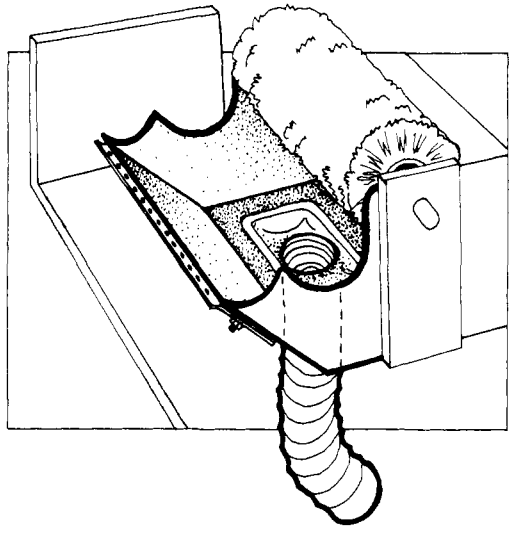

Figure 3. Diagram of hopper, brush, and scaper for collection of press cake.

a small-batch processor, it works quite satisfactorily.

Sample Preparation. Dawson alfalfa at approximately 0.1 bloom and grown at The University of Nebraska Field Laboratory at Mead was cut with a sickle mower at 9:00 a.m., gathered into plastic bags, and transported to Lincoln. The alfalfa was chopped in an Ohio forage chopper to about 1-cm length by 11:00 a.m. The chopped forage, about 50 kg, was thoroughly blended by shovel repiling.

Standard preparation of press samples involved macerating 2 kg of chopped alfalfa in a Hobart food chopper, with the addition of 200 mL of tap water, for 1 min. For the first series of tests, 2 kg of macerated forage was weighed for pressing; for the second series, the entire macerated forage from 2 kg of chopped forage was pressed.

Different forage temperatures were obtained by cooling or heating the chopped forage in plastic cooking bags to minimize moisture changes. A refrigerated room and a freezer were used for cooling, and a microwave oven was used for heating. Forage temperatures were measured before and after maceration by a five-point averaging, digital thermocouple thermometer. Samples were pressed immediately after macerating.

Sample Processing. Samples of chopped or macerated forage (100–200 g) and the press cake were blanched for 3 min in a microwave oven, frozen, freeze-dried, and ground. Press juice was centrifuged at 10000*g* for 20 min to separate the chloroplastic and cytoplasmic fractions. The pigmented centrifugate was considered to be the chloroplastic fraction and the effluent the cytoplasmic fraction, although it is recognized that the effluent contains some chloroplastic material. All dried material was ground with a Jacobson Model 66B pulverator (Jacobson Machine Co., Minneapolis, MN) dressed with a $^3/_{64}$-in. screen.

Analyses for crude protein, crude fiber, dry matter, ash, carotene, and xanthophyll were conducted by using AOAC methods (AOAC, 1975).

RESULTS AND DISCUSSION

Dry matter recovery in the press cake, 54–62%, was lower than that reported by Bruhn and Koegel (1974), 76%, by Knuckles et al. (1970), 66–81%, or by Kehr et al. (1979), 80%; thus, that in the press juice was higher. Protein recovery in the press cake, 32–50%, was less than that reported by Knuckles et al. (1970), 55–73%, or by Kehr et al. (1979), 64–77%. Differences in the pressing equipment used account for these varying dry matter and protein recoveries. Total carotenoid recovery was similar to that reported by Knuckles et al. (1970).

Forage temperatures before pressing in the first series were 7, 25 (ambient), 36, 50, and 60 °C and in the second series 3 (frozen), 14, 25, and 35 °C. The dry matter yield of all fractions did not appear to be affected by heating or cooling. Protein content and recovery (Tables I and II) in the cytoplasmic fraction decreased with heating while those of the press cake and chloroplastic fractions increased. No changes were observed on cooling or freezing. Carotene and xanthophyll content and recovery (Tables I and II) decreased with heating in the chloroplastic

Table II. Effect of Forage Temperature on Constituent Contents and Yield of Pressed Alfalfa Cut on 9-12-78

		forage temperature, °C			
		3	14	25	35
dry matter content, %[a]	forage	18.6	18.6	18.7	18.4
	press juice	9.4	9.5	9.6	8.5
dry matter recovery, %	press cake	59.5	57.4	61.9	54.4
	chloroplast	17.8	18.1	16.0	18.1
	cytoplasm	16.4	16.6	17.2	13.0
protein content, %	forage	18.5	18.5	18.5	18.5
	press cake	12.0	12.0	12.5	11.3
	chloroplast	30.2	29.5	31.2	30.6
	cytoplasm	35.6	35.5	35.2	34.5
protein recovery, %	press cake	38.6	37.2	41.7	33.0
	chloroplast	29.1	28.8	26.9	29.9
	cytoplasm	31.6	31.8	32.7	24.3
carotene content, mg/kg	forage	252	243	202	237
	press cake	66	59	53	57
	chloroplast	655	655	625	579
	cytoplasm	47	38	18	57
carotene recovery, %	press cake	15.6	13.9	16.2	13.1
	chloroplast	46.4	48.7	49.5	44.2
	cytoplasm	3.0	2.6	1.6	3.1
xanthophyll content, mg/kg	forage	343	331	304	326
	press cake	102	95	97	97
	chloroplast	1037	972	984	959
	cytoplasm	36	27	20	48
xanthophyll recovery, %	press cake	17.7	16.5	19.7	16.2
	chloroplast	54.4	53.1	51.7	53.3
	cytoplasm	1.7	1.4	1.2	1.9

[a] Wet basis; all other values are on a dry basis.

Table III. Effect of Maceration and Added Water on Constituent Contents and Yield of Pressed Alfalfa Products[a]

		trial 1			trial 2			
	maceration:	+	+	−	+	+	−	−
	added water:	+	−	−	+	−	+	−
dry matter content,[a]	forage	21.5	23.6	23.2	18.7	18.5	18.9	18.7
	press juice	16.2	16.2	15.4	9.6	10.7	8.7	9.4
dry matter recovery, %	press cake	55.1	56.9	60.9	61.9	55.4	69.2	69.9
	chloroplast	19.5	21.6	20.5	16.0	17.1	11.6	11.8
	cytoplasm	19.8	18.2	16.8	17.2	16.0	15.0	13.8
protein content, %	forage	17.2	17.2	17.2	18.5	18.5	18.5	18.5
	press cake	10.0	10.3	10.0	12.5	12.5	14.3	13.9
	chloroplast	24.4	25.3	26.3	31.2	30.2	31.0	31.8
	cytoplasm	33.3	33.4	32.2	35.2	35.4	32.3	33.4
protein recovery, %	press cake	32.2	34.0	35.5	41.7	35.2	53.3	52.5
	chloroplast	23.6	31.8	31.4	26.9	27.9	19.4	20.3
	cytoplasm	38.4	35.3	31.6	32.7	30.6	26.2	25.0
carotene content, mg/kg	forage	205	233	268	202	250	214	239
	press cake	48	53	62	53	54	76	78
	chloroplast	514	537	524	625	608	690	733
	cytoplasm	159	136	155	18	58	64	59
carotene recovery, %	press cake	12.9	12.9	14.1	16.2	12.0	24.6	22.8
	chloroplast	49.0	49.9	40.0	49.5	41.7	37.3	36.2
	cytoplasm	15.3	10.6	9.8	1.6	3.7	4.4	3.5
xanthophyll content, mg/kg	forage	271	300	308	304	345	300	333
	press cake	75	75	88	97	91	126	123
	chloroplast	750	779	524	984	962	1075	1147
	cytoplasm	165	140	159	20	45	52	45
xanthophyll recovery, %	press cake	15.3	14.2	17.3	19.7	14.6	29.1	25.8
	chloroplast	54.1	56.2	34.8	51.7	47.8	41.5	40.6
	cytoplasm	12.0	8.5	8.7	1.2	2.1	2.6	1.8

[a] Wet basis; all other values are on a dry basis.

fraction as well as in the cytoplasmic fraction, but only small quantities were present in the cytoplasm. Carotene and xanthophyll contents and recoveries increased in the press cake with heating, particularly at 60 °C. At this temperature, blanching would start to have an effect. Fiber and ash content and recovery of the fractions were not affected by heating or cooling.

Halverson (1962) reported decreased dry matter, as well as N, in press juice as forage temperature was increased. Alfalfa harvested on frosty mornings and roll pressed while partially frozen had less than 5% carotenoid loss compared to the 20% loss observed on a warm summer day (Knuckles et al., 1970). Heating forage before pressing was suggested as a procedure for dewatering with minimum N extraction (Jones, 1977) and as a method of expressing cytoplasmic protein (Mathismoen, 1975; Gastineau, 1976; Pirie, 1977).

Maceration of forage has been shown to be necessary for efficient dry matter and protein extraction by pressing (Edwards et al., 1978; Koegel et al., 1973). The results of this study (Table III) show an agreement with others' assessment of the need for maceration. The data also show

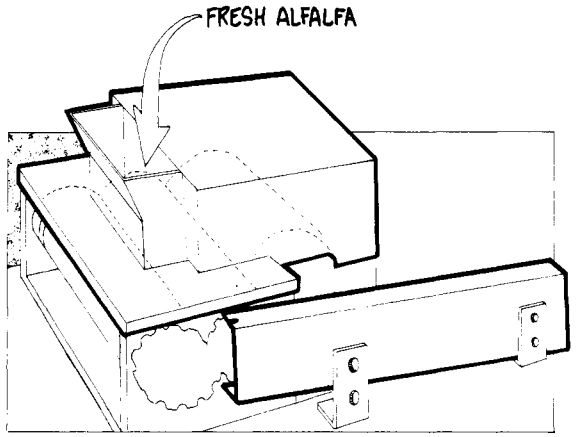

Figure 4. Diagram of press showing safety shields and feed hopper.

an increased efficiency of carotenoid extraction.

Alfalfa dry matter (DM) content was shown by Edwards et al. (1978) to have a small negative correlation with LPC yield while other previous studies have reported that added moisture is apparently desirable (Shepperson et al., 1977). In this study, the addition of water did not appear to be critical (Table III) with the forage used (18–21% DM) but may be with drier forage.

The high fiber content (12%) of the chloroplastic fraction, as well as the low protein content (11%) of the press cake, indicated that the forage was overpressed based on normal nutritional standards. Previous workers have shown crude fiber contents of press juice, chloroplastic fraction, and leaf protein concentrates to be less than 3% (Halverson, 1962; Hartman et al., 1967; Spencer et al., 1971; Knuckles et al., 1970, 1972; Edwards et al., 1977).

The high fiber level was undoubtedly due to the lack of clearance between the rolls which, because of slippage between the rolls and forage, caused additional and excessive maceration. Fiber in the press juice was of small particle size which would pass through the usual screen used to remove fiber; thus, no attempt was made to remove fiber from the press juice.

The protein content of the press cake in this study was less than that shown by Hartman et al. (1967), Knuckles et al. (1970), and Edwards et al. (1978). The protein content of dehydrated press cake should be at least 15% to meet dehydrated alfalfa standards of quality or to be practical for inclusion in ruminant rations according to The University of Nebraska animal scientists.

Ash content of the fractions was not affected by any of the treatments but was dependent on that of the original forage.

The gap between the rolls was not a variable in the design of the experiments because the double-roll press design does not allow for any gap. If there was a gap, the juice expressed would be reabsorbed or at least reincorporated with the press cake after passing between the rolls.

The pressure on the rolls was not monitored during this study. The machine was not designed with this capability. Experience indicates, however, that the higher the pressure, the higher the expression efficiency. On the other hand, higher roll pressure also results in significant bearing wear.

The rolls had a constant peripheral speed of approximately 0.15 m/s. Variations in roll speed would have more influence on machine capacity than on expression efficiency for the press design used.

In further studies on forage maturity, cultivars, etc., standard procedures will be to freeze the chopped forage until pressing and to macerate and press the equivalent at 400 g of dry matter with the addition of water to bring the macerated forage to 20% dry matter. Modification will be made so the press roll tightness can be torqued to a known and constant level. With this capability, lower roll pressures can be used to reduce the amount of protein expressed and the amount of fiber in the green juice.

CONCLUSIONS

The operation of the laboratory model press for the expression of juice from alfalfa has been quite satisfactory. It is a reasonable design for studying forage variables or where small amounts of juice or press cake are needed for research work.

Cooling had no effect on the expression of alfalfa juice while heating generally had detrimental effects. Maceration of the forage before pressing proved advantageous. The value of increasing the moisture content of forage before pressing was indeterminate in this study, but it may be significant with lower moisture content forage.

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