

THE UNIVERSITY OF MANITOBA

CHEMICAL AND ORGANOLEPTIC EVALUATION OF MEMBRANE FILTERED
APPLE JUICE PRODUCED FROM MANITOBA GROWN
APPLES AND CRABAPPLES.

by
Vincent D'Souza

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF FOOD SCIENCE
WINNIPEG, MANITOBA
MARCH, 1986



Permission has been granted to the National Library of Canada to microfilm this thesis and to lend or sell copies of the film.

The author (copyright owner) has reserved other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without his/her written permission.

L'autorisation a été accordée à la Bibliothèque nationale du Canada de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur (titulaire du droit d'auteur) se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation écrite.

ISBN 0-315-33960-8

CHEMICAL AND ORGANOLEPTIC EVALUATION OF MEMBRANE FILTERED
APPLE JUICE PRODUCED FROM MANITOBA GROWN
APPLES AND CRABAPPLES

BY

VINCENT D'SOUZA

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

© 1986

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this thesis, to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

DEDICATION

TO MY PARENTS, BROTHERS AND SISTERS, AND TO
ROSE AND FILOMENO CARVALHO.

ACKNOWLEDGEMENTS

First of all, I am indeed grateful to my advisor, Dr. M.B. McConnell, for his valuable advice during the course of this study and for his constructive criticisms, suggestions and patience during the preparation of the manuscript.

I also wish to express my gratitude to Dr. E.D. Murray, who provided guidance from the very beginning of my study at the University of Manitoba. The assistance and advice of Dr. R.A. Gallop, Dr. G. Mazza and Professor R. Diamant are greatly appreciated.

The assistance of Mr. P. Stephen in the statistical analysis of the data and computational work, to Mr. J. Rogers for his assistance with HPLC analysis was also truly appreciated by the author.

Special acknowledgements are due to Miss Donna Ryland and Lois Jeffery for their assistance, advice regarding sensory evaluation and driving me to Morden, Manitoba to pick the apples. I wish to thank the nine conscientious panel members from Foods and Nutrition and Dept. of Food Science.

I would like to thank Mario and Celine Carvalho, Leslie and Violet Carvalho, Rohini and Stan Amaladas, Francis and Gemma Soares, and D.D. Sharma for their encouragement and moral support.

My sincere thanks also go to John and Angela D'Souza (uncle and aunt) my friends John Borges, Marilyn Estibeiro and Mangal Sarraff for continuous encouragement and moral support through all their letters during the course of this study.

Finally, a special word of thanks goes to Lorraine Mascarenhas for her continuous encouragement and moral support.

ABSTRACT

A two year study was undertaken to assess the chemical and organoleptic qualities of one crabapple and nine apple cultivars grown on the Canadian Prairies for commercial production of apple juice. Considerable variation was observed among the cultivars for moisture (82.24% - 88.19%), acids (0.49% - 1.09%), sugars (9.00% - 13.84%) and phenolics (0.31% - 0.53%). A pilot plant scale filtration assembly was utilized in this study. Pectinase concentration of 0.15%(w/v) was most efficient in clarification of raw apple juice. The enzyme clarified apple juice was pumped through a cartridge membrane filtration system ranging from 106 to 0.22u for clarification, polishing and sterilization. The cartridge membrane filters reduced the turbidity of the juice from 106 to 0.3 JTU (Jackson Turbidity Unit). Yeast and mold counts were nil on the final product. Organoleptic studies revealed that perceived sweetness increased as the sugar-acid ratio increased, while sourness increased with a decrease in sugar-acid ratio. Breakey and Collet cultivars had the acceptable sugar-acid ratio required to make single cultivar juice. The other cultivars were less suitable due to wider range of compositional differences. The blended juices prepared from the sample juices compared very well with commercial apple juice.

TABLE OF CONTENTS

DEDICATION

ACKNOWLEDGEMENTS

ABSTRACT

TABLE OF CONTENTS i

LIST OF TABLES vi

LIST OF FIGURES ix

APPENDICES xii

INTRODUCTION 1

2. LITERATURE REVIEW 3

2.1. General: 3

2.2. Processing Parameters for Apples 3

2.2.1. Soundness 3

2.2.2. Maturity 5

2.3. Juice Processing 7

2.3.1. Clarification 7

2.3.1.1. Enzyme Clarification 7

2.3.1.2. Clarification Mechanism 10

2.3.1.3. Sedimentation in Clarified Apple
Juice 10

2.3.1.4. Effect of Clarification on Juice
Quality 12

2.3.2. Membrane Filtration	12
2.3.2.1. Sterilization of Apple Juice by Filtration	14
2.3.2.2. Turbidity and Filter Performance . .	15
2.3.2.3. Economical and Regulatory Aspects . .	16
2.3.2.4. Effect of Filtration from the Sen- sory Point of View	17
2.4. Correlation Between Analytical, Sensory and Instrumental Measurements in Apples and Apple Juice	18
2.4.1. Chemical Analysis of Apples	20
2.4.2. High Performance Liquid Chromatographic Determination of Sugars and Acids in Apple Juice	21
2.4.3. Quantitative Descriptive Analysis	23
2.4.4. Blending	24
2.4.5. Effect of Time and Temperature on the Sen- sory Quality of Apple Juice	26
3. MATERIALS AND METHODS	27
3.1. Source of Material	27
3.1.1. Sample Preparation	27
3.1.2. Analytical Methods and Statistical Analysis . .	28

3.2. Filtration Process	28
3.2.1. Apparatus	29
3.2.2. Filtration Assembly	29
3.2.3. Clarification Test	34
3.2.4. Pectin Test (Alcohol Method)	34
3.2.5. Juice Preparation	34
3.2.6. Filtration Process	35
3.2.7. Samples, Analytical Methods and Statistical Analysis	36
3.2.8. Plate Counts for Yeasts and Molds in Apple Juice	36
3.3. Sensory Evaluation	37
3.3.1. Sample Selection and Preparation	37
3.3.2. Panel Selection	37
3.3.3. Selection of Vocabulary	38
3.3.4. Panel Training	38
3.3.5. Sample Presentation	39
3.3.6. Statistical Evaluation of Sensory Data	40

3.4. Chromatographic Analysis of Sugars and Acids in	
Apple Juice	42
3.4.1. Sample Preparation	42
3.4.2. Apparatus	43
3.4.3. Eluent Preparation	43
3.4.4. Operating Conditions	43
3.4.5. Expression of Results and Statistical Anal-	
ysis	44
4. RESULTS AND DISCUSSION	45
4.1. Moisture Content (Fruit)	45
4.1.2. Total Acidity (Fruit)	45
4.1.3. Total Soluble Solids (Fruit)	45
4.1.4. Total Polyphenolic Content (Fruit)	49
4.2. Filtration Process of Apple Juice	50
4.2.1. Apple Juice Clarification With Pectinase	51
4.2.2. Filtration Efficiency of Apple Juice	51
4.2.3. Recycling of Apple Juice	55
4.2.4. Filter Performance During Filtration	55

4.2.5. Flow Rate and Pressure	66
4.2.6. Effect of Filtration on the Chemical Composition of Apple Juice	68
4.3.1. Total Acid and pH in Apple Juice	70
4.3.2. Total Sugar and Total Phenolic Contents in Apple Juice	73
4.3.3. Sugar-Acid Ratio of Apple Juice from Manitoba grown Apple and Crabapple Cultivars . . .	76
4.3.4. Analysis of Sugars in Apple Juice by HPLC . .	76
4.3.5. Organic Acid Determination in Apple Juice by HPLC	82
4.3.6. Comparison of Official and HPLC Methods for the Determination of Total Sugar and Acid Content in Apple Juice	86
4.4. Sensory Evaluation of Apple Juice	87
4.4.1. Aroma Evaluation of Apple Juice	87
4.4.2. Flavor (by mouth) Evaluation Of Apple Juice	94
4.4.2.1. Apple Flavor	96
4.4.2.2. Sweetness	96
4.4.2.3. Sourness	99
4.4.2.4. Astringency	105

4.4.3. Descriptive Flavor Profile Of Apple Juice . .	105
4.4.4. Effect of Sugar-Acid Ratio on Perceived Sweetness and Sourness	113
5. CONCLUSION	122
6. RECOMMENDATIONS	124
7. BIBLIOGRAPHY	125

LIST OF TABLES

Table 1. Classification of products processed from apples . . .	4
Table 2. Moisture content of Manitoba grown apple and crabapple cultivars	46
Table 3. Acid content (% Malic Acid) of Manitoba grown apple and crabapple cultivars	47
Table 4. Sugar content (% Sucrose) of Manitoba grown apple and crabapple cultivars	48
Table 5. Phenolic content (% Tannic Acid) of Manitoba grown apple and crabapple cultivars	50
Table 6. Effect of enzyme concentration on the rate of depectination of apple juice at room temperature . .	52
Table 7. Mean turbidity value for apple juice	64
Table 8. Plate count for yeast and mold in apple juice. . . .	65
Table 9. Flow rate and pressure during fine filtration of apple juice	67
Table 10. Chemical changes observed in apple juice (Collet) during the filtration process . . .	69
Table 11. Acid content (%Malic Acid) of apple and crabapple juice	71
Table 12. pH of apple and crabapple juice	72

Table 13. Sugar content (% Sucrose) of apple and crabapple juice	74
Table 14. Phenolic content (% Tannic Acid) of apple and crabapple juice	75
Table 15. Sugar-Acid ratio of apple juice from Manitoba grown apple and crabapple cultivars	77
Table 16. Mean sugar content of apple juice (1983 and 1984) as determined by HPLC	78
Table 17. Organic acids in apple juice (1983 and 1984) as determined by HPLC	83
Table 18. Cultivar mean score for fermented aroma in apple juice	93
Table 19. Cultivar mean score for apple aroma in apple juice	95
Table 20. Cultivar mean score for apple flavor in apple juice	97
Table 21. Cultivar mean score for sweetness in apple juice .	98
Table 22. Cultivar mean score for sourness in apple juice . .	104
Table 23. Cultivar mean score for astringency of apple juice	110

Table 24. Chemical and sensory analyses of blended and commercial apple juice	116
--	-----

LIST OF FIGURES

Figure 1. Pilot plant cartridge membrane filtration system utilized for filtration and sterilization of apple juice	30
Figure 2. Flow diagram of filtration assembly	32
Figure 3. Ballot used for the evaluation of aroma in apple juice	40
Figure 4. Ballot used for the evaluation of flavor in apple juice	41
Figure 5. Alcohol test for detection of pectin in clari- fied apple juice	53
Figure 6. Filtration efficiency of apple juice	56
Figure 7. Degree of turbidity on recycling	59
Figure 8. Filter performance during filtration	61
Figure 9. Typical HPLC chromatogram of sugars in apple juice (Collet, 1984)	79
Figure 10. Typical HPLC chromatogram of organic acids in apple juice (Collet, 1984)	84
Figure 11. Comparison of sugar analysis in apple juice by Official and HPLC methods	88
Figure 12. Comparison of total acidity analysis in apple	

juice by Official and HPLC methods	90
Figure 13. Correlation between perceived sweetness by sensory panel with sugar content by the Official method	100
Figure 14. Correlation between perceived sweetness by sensory panel with sugar content by HPLC	102
Figure 15. Correlation between perceived sourness by sensory panel with acid content by Official method	106
Figure 16. Correlation between perceived sourness by sensory panel with acid content by HPLC	108
Figure 17. Correlation between perceived astringency by sensory panel with tannin content by the Official method	111
Figure 18. Descriptive flavor profile of apple juice	114
Figure 19. Relationship of perceived sweetness against sugar-acid ratio	118
Figure 20. Relationship of perceived sourness against sugar-acid ratio	120

Leaf inserted to correct page numbering

APPENDICES

Appendix 1.	Procedure utilized for blending of apple juice	133
Appendix 2.	Prepared blend of apple juice	134
Appendix 3.	Concentration of taste stimuli used in orientation panels	135
Appendix 4.	Questionnaire for ranking	136
Appendix 5.	Description of apple juice	137
Appendix 6.	Sensory attributes selected by panel for evaluation of apple juice	138
Appendix 7.	Reference samples used during aroma and flavor evaluation	139
Appendix 8.	The sequence of sample presentation for aroma evaluation in apple juice	140
Appendix 9.	The sequence of sample presentation for flavor evaluation (by mouth) in apple juice	141
Appendix 10.	Sugars present in apple juice (1983) as determined by HPLC	142
Appendix 11.	Sugars in apple juice (1984) as determined by HPLC	143
Appendix 12.	Organic acids present in apple juice (1983) as determined by HPLC	144
Appendix 13.	Organic acids present in apple juice (1984) as determined by HPLC	145
Appendix 14.	Analysis of variance for fermented aroma in apple juice	146
Appendix 15.	Mean scores of replicates for fermented aroma in apple juice	147

Appendix 16.	Analysis of variance for apple aroma in apple juice	148
Appendix 17.	Analysis of variance for apple flavor in apple juice	149
Appendix 18.	Analysis of variance for sweetness in apple juice	150
Appendix 19.	Mean cultivar scores for sweetness versus total sugar content determined by Official Methods and HPLC analysis	151
Appendix 20.	Analysis of variance for sourness in apple juice	152
Appendix 21.	Mean cultivar scores for sourness versus total acidity determined by Official methods and HPLC analysis	153
Appendix 22.	Analysis of variance for astringency in apple juice	154
Appendix 23.	Mean cultivar scores for astringency versus total phenolics determined by Official methods	155
Appendix 24.	Mean cultivar scores for sweetness and sourness versus sugar-acid ratio (A.O.A.C.)	156

INTRODUCTION

Apple production on the Canadian Prairies has received strong support from the various segments of the Horticulture Industry since the 1930's. Unfortunately the rigorous climatic conditions have prevented the utilization of the major apple cultivars. The Western Canadian Society for Horticulture initiated the Cooperative Fruit Breeding Program in the 1940's to select and propagate hardy fruits suitable in the Prairie region. There were three phases in this program: 1) several crosses made at Morden, Manitoba were distributed to other Prairie testing sites (ie. Brooks, Alberta and Melfort, Saskatchewan); 2) selections were made from the crosses based on the hardiness, resistance to disease and overall fruit quality; 3) these selections were then named and released to the commercial trade. The ultimate objective of the program was to have tree fruits in every farmstead. At no time was the program identified with the establishment of commercial orchards on the Prairies.

The per capita consumption of apple juice has increased dramatically in the last decade from 4.18 kg in 1970 to 8.50 kg in 1981. Changes in the life style and improvements in juice quality through developments in juice processing technology are two possible reasons for the increased popularity of apple juice. The apples developed by the Cooperative Fruit Breeding program have become popular in the rural communities on the Prairies for juice because of their unique strong apple flavors. Their potential for this industry is unknown at this time.

The Food Science Department and the Agriculture Canada

Research Station at Morden, Manitoba initiated a program of studies designed to assess the food quality characteristics of some of the apple cultivars selected by the Cooperative Fruit Breeding Program. It has generally been stated that these cultivars will not produce fruit acceptable for the fresh trade because they are smaller in size than normal commercial apples. Prior to this study these cultivars have never been evaluated for the production of processed products. Hence this two year study (1983 and 1984) was the completion of a three year program to characterize the overall quality of one crabapple and nine apple cultivars.

The specific objectives of this study were:

1. to analyze the fruit for moisture, pH, acidity, soluble solids, and phenolic content.
2. to process the fruit into juice utilizing a cartridge membrane filtration system and to evaluate the efficiency of this system for a small juice processing plant.
3. to analyze the juice for pH, acidity, sugars and phenolic content.
4. to assess the sensory qualities of the juices from ten cultivars.
5. to evaluate the potential of the juice from the cultivars used in this study for commercial apple juice.

2. LITERATURE REVIEW

2.1. General:

Commercial production of canned and bottled apple juice started in North America about 1937 (Moyer and Aitken, 1980). It has gradually increased in importance since that time. A strong cottage industry for the production of apple cider had developed in the major apple producing regions of North America prior to the 1950's. Today, apples are processed into a wide variety of products which are classified as liquid, solid, or pureed products (Table 1). According to La Belle (1981), apples may differ in size, shape, specific gravity, color, firmness, soluble solids, acidity, and pH because of variety, maturity, or postharvest conditions. The importance of various quality characteristics for the processing of apple juice is presented in the following section.

2.2. Processing Parameters for Apples

Alston (1979) classified the fruit into four categories: eating quality, appearance, storage quality and processing quality. The fruit used for juice is normally second grade (Smock and Neubert, 1950). According to Moyer and Aitken (1980), juice manufacturers use varieties which are available in surplus or rejected from the fresh fruit market mainly due to their physical injury, size, shape, color and blemishes.

2.2.1. Soundness

In order to produce a good quality juice, the apples should

Table 1. Classification of products processed from apples

<u>Liquid</u>	<u>Solid</u>	<u>Pureed</u>
Cider(fresh)	Baked whole apple	Apple sauce (including baby food)
Juice(fresh or pasteurized)	Slices or pieces	
Juice or concentrate	Fresh	Nectar
Hard (fermented cider)	Frozen	Apple butter
Wine	Dehydrofrozen	
Vinegar	Rings (canned, spiced)	

Adapted from La Belle (1981).

not be wholly or partially decayed because these can impart a "moldy" flavor to the juice. According to Moyer and Aitken (1980), decayed fruits produce Patulin a mycotoxin. Recently, Roland et al. (1984) reported that Patulin is highly toxic and has been shown to be carcinogenic in laboratory animals. Patulin is produced by Penicillium expansum, P. patulum and Aspergillus lavatus (Moyer and Aitken, 1980; Scott and Bullerman, 1975). Other blemishes and defects seem to have little effect on the quality of the juice. For example, Moyer and Aitken (1980) reported that scab, scale spots and aphid injury do not adversely affect the quality of juice. However, Smock and Neubert (1950) reported that a physiological disease known as "cork" seriously injures the quality of apples and results in lower yield without contributing any off-flavor.

2.2.2. Maturity

Maturity of apples is perhaps the most important factor in the production of apple juice. The immature and overmature apples seem to be unsuitable for the production of juice. According to Moyer and Aitken (1980), immature apples tend to have high acid and an astringent taste. They lack in sweetness, apple flavor and impart a "starchy" or green apple taste due to a high percentage of starch. Krishnaprakash et al. (1985) observed that the position of the apple on the tree influenced the rate of maturation. Fruits at the bottom of the tree matured earlier than those at the middle and the top. They suggested that it is desirable to harvest apples from the bottom half of the tree earlier than the

top with a gap of 7-10 days between harvests. Improvement in the quality of the juice is due to the conversion of starch into sugars (Moyer and Aitken, 1980). Sapers et al. (1977) reported that with different harvest times (maturities) there was a decrease in acidity, with an increase in soluble solids and volatile composition in McIntosh apples. According to Bradley and Brown (1969), fruit from the early and midpicking season was unsuitable for juice processing. After a certain period of storage, however, it develops satisfactory processing characteristics. These beneficial storage changes are due to the breakdown of starch which results in an increase in the sugar content of the fruit. Hence, with storage and maturity the quality of the juice is improved mainly due to an increase in sugar content (sweetness), a decrease in acidity (sourness), and an increase in the volatile composition (aroma) of the apples.

On the other hand, overmature apples are unsuitable for juice production because they are difficult to press, filter, and clarify, thus resulting in a low yield. The juice is of a poor quality lacking in flavor. LaBelle (1981) reported that overripe apples have high levels of suspended solids in the juice. Even though the suspended solids are removed during clarification, the filtration efficiency and juice yield are affected by their high level. Overmature fruit is more susceptible to mealiness, fungal disease and breakdown due to senescence (Anonymous, 1974). There is no easy way to make an exact assessment of maturity. Indices of maturity include skin color, flesh color, seed color, starch content, ease of picking and the Magness Taylor pressure

test (Anonymous, 1974).

2.3. Juice Processing

2.3.1. Clarification

North American consumers prefer apple juice free from suspended solids. However, fresh apple juice has a cloudy appearance due to the presence of suspended solids. Suspended solids are colloidal in nature because they consist of mucilaginous, hydrophillic gums and pectic substances (Mian and Bhatti, 1969; Smock and Neubert, 1950). Clarification of apple juice is necessary in order to prevent the rapid clogging of filters during the filtration process (Moyer and Aitken, 1980).

To accomplish clarification numerous methods have been proposed. It is based on the ability to disrupt the colloidal system which can be achieved by chemical or mechanical means. Carpenter et al. (1932) recommended that the juice be flash heated to 82°C for twenty seconds and cooled immediately to coagulate the suspended particles. Probably the best known and most widely used methods are the gelatin-tannin and enzyme (pectinase) methods for clarifying apple juice. Small amounts of pectic enzymes occur naturally in fresh apple juice (Anonymous, 1982). According to Smock and Neubert (1950), clarification must be fairly rapid to prevent fermentation. Therefore, pectinase enzyme must be added to reduce the time requirement for clarification so that fermentation will not occur during treatment.

2.3.1.1. Enzyme Clarification

The filtration procedure is simplified if the juice is subjected to enzyme clarification which is capable of disrupting the colloidal system. Pectin is a protective colloid which retards the settling of particles. Pectin is made up primarily of (1-4) α -D-polygalacturonic acid in which two thirds of the carboxylic groups are esterified (Eskin et al. 1971). Product characteristics affected by pectin include viscosity, color stability, clarity and possibly flavor (Kilara, 1982). Hence it is necessary to depolymerize the pectin with pectinase during clarification. The commercial term "pectinase" is given to an enzyme preparation which is obtained from molds of the genus Aspergillus (Kilara, 1982). It is available in liquid and dry powder form. It consists of a mixture of polygalacturonase and pectin esterase (Smock and Neubert, 1950). The enzyme has the ability to hydrolyze pectin and reduce the viscosity of the juice thus making it easier to filter.

A number of enzyme preparations have been employed to clarify apple juice. Early investigations include the use of protein and starch splitting enzymes (Smock and Neubert, 1950). These enzymes were not able to produce filterable juice due to the fact starch and protein substances are only minor constituents of apple juice. Recently, McLellan et al. (1985) suggested the use of honey and enzyme separately and in combination for clarification of apple juice. They also reported that the combined treatment of enzyme and honey induced rapid flocculation as compared to enzyme alone at cold as well as warm temperatures. McLellan et al. (1985) recommended the use of 1.0% honey for clarifica-

tion. The exact mechanism of clarification with honey or honey plus enzyme is still not clear, but it is assumed to be a protein-tannin reaction which is similar to the commercial gelatin-tannin method (Kime, 1983). Mian and Bhatti (1969) recommended the use of pectinol enzyme (0.1%) and bentonite (0.5-0.6%). However, Moyer and Aitken (1980) suggested that tests be carried out to establish the proper enzyme concentration.

Parameters affecting clarification are pH, temperature, contact time and enzyme concentration. The pH is influenced by variety and maturity. The pH of apple juice is between 3.2-4.0, falling within or slightly below the optimum range exhibited by most commercial enzymes (Kilara, 1982). McLellan et al. (1985) reported that as temperature increased the rate of clarification increased. Denaturation of the enzyme was observed at higher temperature (45-60°C) (Kilara, 1982). Commercially available enzyme contains 0.005 to 0.01% gelatin. It seems that gelatin helps in clarification by forming a gelatin-tannin complex. Gelatin is positively charged, whereas the colloidal material dispersed in apple juice is negatively charged, thus the oppositely charged particles coalesce and precipitate. It is still not clear if gelatin promotes floc formation or speeds up pectinase action by removing inhibitors such as tannins (Hathaway and Seakins, 1958). According to Moyer and Aitken (1980), gelatin cuts the clarification time in half whereas, Smock and Neubert (1950) reported that gelatin stabilizes the enzyme in solution. In general, the time required for clarification is inversely proportional to the concentration of the enzyme used at constant temp-

erature (5-50°C) and treatment time (2-16 hours).

2.3.1.2. Clarification Mechanism

The mechanism of clarification can be divided into three distinct stages:

1. Enzyme Hydrolysis
2. Flocculation
3. Sedimentation

Freshly pressed apple juice has a cloudy appearance due to the presence of suspended particles. Pectin prevents the settling of particles due to its colloidal properties. Baumann (1981) observed that spontaneous clarification was not possible because pectin prevented proteins from reacting with polyphenols. He further stated that each stage of clarification is influenced by viscosity.

In the first stage of clarification the colloidal properties of pectin are disrupted by the addition of the enzyme due to enzymic hydrolysis. Baumann (1981) reported that the second stage of clarification will occur only when the viscosity is decreased. This can be achieved when 5-10% of the glycosidic linkages are split. The floc formed eventually settles down due to the electrostatic interaction between unlike charges (Kilara, 1982).

2.3.1.3. Sedimentation in Clarified Apple Juice

Clouding followed by sediment formation has been a problem ever since apple juice was first manufactured. It occurs during storage of clarified apple juice. Kilara (1982) termed this defect as "After Haze", that occurs in juice processed at temper-

atures higher than storage temperatures.

Formation of sediments in fermented pear juice was first recorded by Kelhofer in 1908 was reported by Johnson et al. (1968). They concluded that the sediments contained pectin, protein and oxidized tannins. However, Neubert and Veldhuis (1944) reported that the sediment was probably a phlobaphene, a polymeric phenolic material. Kilara (1982) suggested that leucoanthocyanidins and catechins were the precursors of the polymeric phenolic fraction of the sediment formed during the milling and pressing operations. Although chlorogenic acid is one of the principal polyphenols occurring in apples, it is doubtful that it contributes towards sediment formation (Johnson et al., 1968). According to Heatherbell (1976), sediments could arise from incompletely degraded pectins and starch-tannin complexes. It is reported that amylose and/or amylopectin fragments eventually precipitate (retrogradation) and remain in the apple juice during clarification and filtration. Apparently amylose/amylopectin polymers can complex with small amounts of protein and phenolic substances during retrogradation (Heatherbell, 1976). Retrogradation is accelerated at low temperatures by the presence of tannins and proteins (Whistler, 1953).

Sedimentation problems in clarified apple juice could be overcome by the addition of nonacidulated, starch-free, liquid pectin just prior to flash pasteurization (Smock and Neubert, 1950). On the other hand, Hulme (1958) recommended the use of only fully matured or stored apples which have a low starch content.

2.3.1.4. Effect of Clarification on Juice Quality

Several investigators have studied the chemical changes occurring in juice as a result of clarification. According to Smock and Neubert (1950) suspended solids contribute flavor to freshly pressed apple juice, which is lost during clarification. However, the removal of suspended solids is advantageous because cloudy juice tends to develop a cooked flavor. Kilara (1982) observed a reduction in viscosity due to the removal of pectin in the enzyme treated juice whereas McLellan et al. (1985) observed just the opposite in the honey treated juice.

Loss of astringent substances including tannins was observed in enzyme treated juice (Smock and Neubert, 1950). This loss cannot be explained on the basis of enzyme action and is probably due to coprecipitation with other suspended material. The gelatin-tannin treatment has been found to have a variable effect on astringency and the tannin content of apple juice. According to Moyer and Aitken (1980) gelatin-tannin clarification yields juice much lighter in color as compared to enzyme treated juice. McLellan et al. (1985) observed an increase in °Brix and total solids due to an increase in the sugar content of the honey clarified and honey-enzyme treated juice. In short, consumers prefer clear apple juice, but they are very critical about the changes caused in apple juice as a result of the clarification process (Smock and Neubert, 1950).

2.3.2. Membrane Filtration

Since the early 19th century, the traditional plate and frame

filter press incorporated mainly with an asbestos sheet was used for the clarification and sterilization of juices (Wale, 1982). However, the plate and frame filter press had its own disadvantages like leakage problems, plate gasket alignment, contamination of the exposed filter sheet, and the long cumbersome set up procedures involved. Fiore and Babineau (1979) reported health hazards like pulmonary fibrosis, bronchogenic carcinoma and gastrointestinal tract cancer with the asbestos material. Asbestos fibers were also found in beer (Biles and Emerson, 1968). In 1976 the FDA restricted the use of filters containing asbestos. Since then the use of membrane filters has greatly increased.

Membranes are made from a variety of synthetic materials including cellulose acetate, cellulose nitrate, polypropylene and polycarbonate. Membrane filters are basically screen-type filters (Rankine, 1983). They have the capacity to remove all particles larger than the pore size of the membrane (Reeves, 1983).

Filtration is defined as the process of separating a solid from a liquid by means of a porous substance through which only the liquid passes. There is no one process which meets all requirements. The first filtration operation is coarse filtration either through a diatomaceous earth filter or a coarse grade of sheet filter. Membrane filters are used prior to bottling in order to ensure complete removal of microorganisms and improve clarity. Filtration is a highly efficient and relatively inexpensive process for product recovery, clarification, and stabilization (Fiore and Babineau, 1979). Stabilization of juice by means of filtration represents:

- a) Energy cost saving
- b) Elimination of heat treatment
- and
- c) Assurance from microbial instabilities.

2.3.2.1. Sterilization of Apple Juice by Filtration

Sterilization of fruit juices has become increasingly important as the fruit juice industry has developed. Schelorn (1953) reported that apple juice could be spoiled by molds, surface yeasts, and lactic and butyric acid bacteria. These microorganisms can cause cloudiness, changes in the organic acid content and production of alcohols. The most common methods used to preserve apple juice are pasteurization, chemical treatment, refrigeration and filtration.

Pasteurization is the most common method used commercially to preserve apple juice. Carpenter et al. (1932) reported that pasteurization of juices resulted in precipitation which rendered the product unattractive to the consumer. They further stated that pasteurization had a detrimental effect on flavor. Carpenter et al. (1932) recommended that fruit juices be sterilized by filtration.

Marshal and Walkley (1951) reported that multiple passage of juice through filter plates reduced the number of microorganisms to zero. Reeves (1983) reported that all the insoluble solids and microorganisms that are larger than the pores are retained on the surface of the membrane and as a result the emerging juice is practically stable. Peleg and Brown (1976) observed a decrease in

the flow rate due to gradual blockage of the membrane pores with microorganisms. They also reported that the output through the membrane was uneconomical due to compression of retained particles on the membrane surface. The retained particles provide a resistance to the flow rate which would be compensated for by increasing the pressure. Reeves (1983) observed that under high differential pressures the membranes allowed the yeasts to pass through due to distortion of the microbial cells. He suggested that fluctuations in the flow rate and pressure should be avoided. Hence, Reeves (1983) recommended the use of membrane filters of 0.45 μm pore size, rather than 0.65 μm pore size for the complete removal of bacteria. The possible advantage offered by the so called "cold sterilization" procedure includes low energy requirements and production of better flavored juice (Smock and Neubert, 1950).

2.3.2.2. Turbidity and Filter Performance

Turbidity can be defined as the optical property of a sample that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample (A.P.H.A., 1975). It can be expressed by a composite relationship (Heimenz, 1977).

$$I/I_0 = \exp [-(a+t)\Delta l]$$

where:

I = Intensity of transmitted light
 I_0 = Intensity of incident light
 a = absorbance
 t = turbidity
 l = light path

Turbidity is expressed as JTU (Jackson Turbidity Unit). It can

also be expressed as FTU (Formazin Turbidity Unit), TU (Turbidity Unit) and NTU (Nephelometer Turbidity Unit).

Turbidity is measured by a photoelectric instrument in terms of intensity of light. The nephelometer measures the intensity of scattered light at a 90° angle to the plane of propagation of the incident light (Simms, 1976). Peleg and Brown (1976) used a turbidimeter to monitor filter performance of wines. They observed that pressure drop was building at a fairly constant flow rate after 20 minutes, which indicated a low turbidity level. Longer filtration cycles were economical from a quality and stability point of view (Peleg and Brown, 1976). Turbidimeters are influenced by the size, shape and refractive index of suspended particles (Black and Hannah, 1965). Hach (1976) suggested that the sample cell should be clean and free from scratches or smudges because glass could cause the light to reflect and scatter. Such stray light gives a false turbidity measurement. Simms (1976) reported that turbidimeters are influenced by bubbles. However, a turbidimeter may tell us if the juice is turbid or not but it will not warn of any microbial load (Peleg and Brown, 1976).

2.3.2.3. Economical and Regulatory Aspects

Economical use of membrane filters is dependent on clarification, pre-filtration procedures and the flow rate at which filtration is conducted. Adequate pre-filtration and the use of appropriate filters can extend the life of the final or sterilizing filter. Clogged filters can often be regenerated by rinsing with water in the forward direction for 10-20 minutes (Neradt,

1981). However, filter regeneration with warm water (55°C) clogged the filters due to denaturation of proteinaceous substances (John, 1982). Both Neradt (1981) and John (1982) recommended that regeneration should be followed by sterilization with hot water at 85-90°C for 20 minutes. Reeves (1983) reported that sterilization by steam could damage the membranes.

The removal of suspended particles is important from the regulatory point of view. According to the Department of National Health and Welfare apple juice:

-"shall have a specific gravity of not less than 1.041 and not more than 1.065 (20°C/20°C), and shall contain in 100 mL measured at a temperature of 20°C, not less than 0.24 g and not more than 0.60 g of ash of which not less than 50% shall be potassium carbonate" (Anonymous, 1981).

Hence, it is important to monitor the changes in the ash content and specific gravity to know whether or not filtration processing could make apple juice unacceptable even without any adulteration.

2.3.2.4. Effect of Filtration from the Sensory Point of View

During filtration, suspended particles and microorganisms are removed thus producing a clear juice. Consumers have shown a preference for clear apple juice (Smock and Neubert, 1950). From the sensory point of view, it is necessary to know the changes in the sugar and tannin content of the juice due to filtration.

However, information available regarding changes in apple juice as a result of filtration is limited. Smock and Neubert (1950) recognized tannins as the constituents of suspended particles. Johnson et al. (1968) reported the changes in the tan-

nin content upon the removal of suspended particles. Information on changes in the sugar and acid contents due to filtration are scarce. According to Charley (1932), filtration of apple juice adversely affected the color and the "body" of apple juice. Neubert (1943) suggested that changes in the viscosity caused the change in the "body" of apple juice. Charley (1932) stated that pectin gave body to apple juice. However, Grove (1930) associated "body" with tannin content rather than pectic substances. Neubert (1943) reported that the "body" of apple juice varied with maturity. This is in agreement with Clague and Fellers (1936) who reported that cider became more viscous as the fruit became more mature, due to the increase in soluble pectin content during storage.

2.4. Correlation Between Analytical, Sensory and Instrumental Measurements in Apples and Apple Juice

The production of apple juice continues to increase because it is consumed as a wholesome and nutritious beverage (McLellan et al., 1984). The product attributes which determine consumer acceptability include appearance, aroma and flavor. Several attempts have been made to correlate analytical, sensory and instrumental measurements by which quality of both apples and their products can be assessed and compared. LaBelle et al. (1960) studied brix, total acidity and brix/acid ratios versus flavor. Poll (1981) evaluated 18 apple varieties both organoleptically and chemically for their suitability for juice production. Voho and Varo (1975) also looked at chemical and

organoleptic qualities of 10 Finnish apple varieties. Analytical measurements such as sugar, acid and polyphenol contents have been used for estimating the quality of apples (Lopez et al., 1958; Poll, 1981; Voho and Varo, 1975). Sensory scores of attributes such as aroma and flavor were correlated with analytical measurements to get an indication of the quality and acceptability of apple juice (Poll, 1981).

Watada et al. (1985) studied sweetness, acidity, crispness, hardness and juiciness of Golden Delicious apples using optical measurements. Guadagni et al. (1966) and Dimick and Hoskin (1981) identified a number of volatile compounds responsible for aroma using gas chromatography. Wilson et al. (1984) investigated flavor differences in the juice produced by ultrafiltration and conventional processing techniques. Esselen (1945) investigated the effect of different methods of clarification on the flavor of apple juices. Carpenter (1933) first reported on the public acceptability of carbonated versus non-carbonated apple juice. Bright and Potter (1979) reported on the overall acceptability of carbonated versus non-carbonated apple juice. McLellan et al. (1984) investigated carbonated apple juice at various levels of soluble solids and carbonations. In recent years, Moskowitz and Von Sydow (1975), Williams (1975) and Durr (1979) have developed the vocabulary to describe aroma in apple juices which is easily understandable and accurately definable. Hence, the combined use of sensory and analytical procedures would give an indication of the relative importance of the characteristics for acceptance and quality.

2.4.1. Chemical Analysis of Apples

Several extensive studies have been made on the chemical composition of apple juice and apple varieties (Lopez et al. , 1958; Kochan, 1968; Bradley and Brown, 1969). The first chemical analysis ever reported on the whole fruit was in 1887 (Lopez et al., 1958). Smock and Neubert (1950) observed considerable variations in the acid, sugar and tannin contents among varieties and within varieties. These variations in the chemical composition are mainly due to the unique weather and growing conditions of the area where the apples are grown. Lopez et al. (1958) looked at the pH, total acidity, soluble solids, sugar, ash and tannin contents in ten Virginia grown apples. Dryden and Hills (1957) studied titratable acidity (TA), brix, and brix/acid ratios.

Each apple producing area has its own favorite juice. Apples that are acceptable in one area may be considered to be poor in another area. A classic example is the McIntosh variety whose juice is considered to be of a mediocre quality in the eastern part of North America, but seems to make a satisfactory juice in the western part (Moyer and Aitken, 1980). Furthermore, Moyer and Aitken (1980) reported that acidity tends to increase among apple varieties grown from South to North. Acidity tends to be low ranging from 0.25 to 0.45% in the south-eastern state in Virginia, in Pennsylvania ranging from 0.35 to 0.55%, while in Nova Scotia acidity tends to be high ranging from 0.45 to 0.88%, all calculated as malic acid on a fresh weight basis.

Data on chemical composition of apples is useful not only for nutritionists but also for processors (Lopez et al., 1958).

According to LaBelle (1981) the desirable characteristics of processing apples include good flavor, firm texture, high tartness, acceptable color and high yield.

2.4.2. High Performance Liquid Chromatographic Determination of Sugars and Acids in Apple Juice

Apple juice is known to contain approximately 85% water, 10-12% carbohydrates, 1% pectin, 0.5% organic acids, 0.5% of various components such as potassium, amino acids, phenolics and small amounts of volatile flavoring compounds (Ryan, 1972). Fructose, glucose and sucrose were reported as the main sugars in apples (Moyer and Aitken, 1980). Presence of sorbitol (alcohol) has also been reported in apples (Minsker, 1962). Malic acid has been reported as the predominating acid with lesser amounts of citric and quinic acids (Moyer and Aitken, 1980). In addition, there have been reports of the presence of glycolic, succinic, lactic and galacturonic acids (Moyer and Aitken, 1980).

For the determination of individual sugars, several time-consuming techniques have been used. These techniques include enzymatic, spectrophotometric and chromatographic procedures (Hurst et al., 1979). The chromatographic procedures most commonly used include paper, thin layer (TLC), and gas liquid (GLC). In gas chromatography, sample preparation is very laborious, especially the derivatization procedure of the sample (Wilson et al., 1981). However, with the advent of high performance liquid chromatography (HPLC), the analysis of foods and beverages has been simplified. The advantages include: rapid analysis, specificity of

analysis, detection at low levels and simplified sample preparation (Coppola, 1984). It performs at room temperature, and unlike gas chromatography does not require high temperatures. An HPLC system consists of a stationary phase, a mobile phase (liquid), a pumping system and a detector. Detectors commonly used are the ultraviolet (UV) and refractive index (RI). Reyes et al. (1982) compared the three analytical methods- HPLC, GLC and enzymic methods for determining sugars and acids. They observed that the %CV (coefficient of variance) was lower for enzymic and HPLC analyses as compared to GLC. The three sugars (fructose, glucose and sucrose) determined quantitatively by HPLC and enzymic methods were in closer agreement than GLC. However, they found a large variation for the acids using the above mentioned methods.

HPLC has also been used to detect adulteration of apple juice (Coppola, 1984; Zyren and Elkin, 1985). Smolensky and Vandercook (1980) reported the presence of grape juice in apple juice. Recently, Zyren and Elkin (1985) detected the presence of high fructose corn syrup and beet sugar in non-authentic apple juice. Evans et al. (1983) and Zyren and Elkin (1985) detected the presence of D-malic acid (synthetic malic acid) which is a clear indication of adulteration because this isomer does not occur naturally in apple juice. Zyren and Elkins (1985) detected fumaric acid (3 mg/L) and concluded that fumaric acid might have occurred as a by-product during the production of synthetic malic acid. However, Evans et al. (1983) reported that fumaric acid would be present as a result of extremes in process-

ing (clarification and concentration processes).

2.4.3. Quantitative Descriptive Analysis

Sensory evaluation is concerned with measuring and evaluating properties of foods using humans as instruments. The potential of humans as an instrument is expandable through selection, motivation and training (Durr, 1979). It is less costly to run tests for differences using trained panelists, rather than large consumer type groups because trained panelists have superior discrimination abilities (Baker and Amerine, 1953). Also, if trained panelists cannot find significant differences between products under test, average consumers would not likely be able to find any either. Even though the field of sensory evaluation is relatively new, it has gained much attention from researchers. Scientists are looking for better methods which can provide maximum information on sensory attributes with least limitations. In view of these rapid changes, the concept of sensory evaluation grew from a "single expert" situation to the "group expert" approach (Stone et al., 1980). As an alternative to the available qualitative procedures, a descriptive procedure that was quantitative and which could be applied to food products was necessary.

A descriptive sensory approach known as the Quantitative Descriptive Analysis (QDA) was first introduced by Stone et al., 1974). In this technique the trained panelists identify and quantify in order of occurrence, the sensory properties of a product or an ingredient. The data are is presented graphically

so that by comparing the profiles of the current products versus the ideal, the product researcher can quickly ascertain how closely two profiles coincide with each other. Literature on the application of QDA methodology is rather limited. Mecredy et al. (1974) used the QDA method to recognize the subtle differences between various beers. The QDA method can be very useful in product development, quality control and product improvement because of its relative ease of implementation and analysis (Stone et al., 1974).

2.4.4. Blending

The juice is of a better quality when two or more varieties are blended, rather than juice from one variety (Moyer and Aitken, 1980; Esselen, 1945). Arengo-Jones (1940) found that the McIntosh apple grown in Ontario and Quebec is extremely useful for blending, but when used alone its flavor was too strong and imparted a perfumed flavor on aging. Blending is normally done at the time of grinding because it is easier to blend the apples rather than making juice from separate varieties and blending them at a later date. The flavor and quality of apple juice is dependent upon the sugar, acid and tannin contents of the apples. The production of high quality juice is dependent upon the above mentioned constituents. Apples vary from variety to variety, from season to season and according to the section of the country where they are grown.

Moyer and Aitken (1980) classified apple varieties into 5 classes:

- I) Acid to Subacid
- II) Subacid to Mild
- III) Aromatic
- IV) Astringent
- V) Neutral.

Apples from Group I are not suitable for single variety juice because of their high acid content. The acidity could be diluted with the addition of 10-20% of the juice from Group II or III or both. This mixture could be blended with some juice of Group IV. According to Smock and Neubert (1950) varieties with higher portions of acid could be utilized at the end of the pressing season because fruit acidity decreases with advanced maturity.

Good quality apple juice is obtained from varieties listed in Group II and III. However, with the addition of 5% of the varieties listed in Group IV the quality of the juice can be further improved. Apples from Group III provide an acceptable flavor. Apple varieties listed in Group IV contribute astringency whereas those in Group V being neutral, could be best utilized to reduce acidity especially those listed in Group I.

Claude and Fellers (1936) emphasized that there is no rule for blending that could prove infallible. According to these workers, the factors to be considered for blending include total acidity, °Brix, tannin content and the pH. Whereas Moyer and Aitken (1980) reported that the flavor of apple juice is based on two factors: (1) sugar-acid balance and (2) aroma. Sugar-acid ratios have been helpful in evaluating apple quality (Lopez et al., 1958). However, sugar-acid ratios are of a relative nature only, that is, the quality cannot be determined by the sugar-acid ratio. For example, McIntosh and Rome Beauty have the

same sugar-acid ratios, but McIntosh is consumed the most (Lopez et al., 1958). A sugar-acid ratio of 15-18 was judged to give the optimal balance of sweetness and sourness (Poll, 1981). Voho and Varo (1975) found that the sugar-acid ratio alone was not a reliable measure of the organoleptic quality in Finnish apples. The sugar-acid balance contributes the sweetness and sourness, astringent taste is contributed by the tannin content and aroma by volatile constituents of the apples (Poll, 1981).

2.4.5. Effect of Time and Temperature on the Sensory Quality of Apple Juice

The critical factors affecting aroma and taste are temperature and time. That is, from the time of production until consumption the juice is likely to undergo a storage period. Literature regarding the influence of storage time and storage temperature on the sensory qualities of the juice is limited.

Aldehydes and esters were responsible for apple aroma (Dimick and Hoskin, 1981). According to Poll (1983a) apart from aldehydes and esters, alcohols were also associated with apple aroma. Changes in the aroma are due to the breakdown of esters, aldehydes and/or alcohols (Dimick and Hoskin, 1981). Poll (1983b) and Nursten and Wolfe (1972) suggested that changes in aroma could be due to Maillard reaction products formed after heating the juice for a long period of time. According to Poll (1983a) the loss in aroma and development of cooked aroma was observed after heating the juice at a higher temperature for a short period of time.

3. MATERIALS AND METHODS

3.1. Source of Material

This study was carried out for two years (1983 and 1984). One crabapple (Kerr) and nine apple cultivars and selections (Breakey, Collet, Goodland, Heyer#12, Norland, PF #36, PF #50, PF #51 and Westland), here after identified as cultivars were selected from the Prairie Tree Fruit Cultivar Cooperative Program, located at the Agriculture Canada Research Station, Morden, Manitoba. Approximately 60 kg lots of each cultivar were hand picked at their proper maturity. Following picking, the apples were transported to the Department of Food Science, University of Manitoba, Winnipeg where they were stored at 85-90% relative humidity and 1-3°C. Three samples (ca 500g each) were selected from each lot for the chemical analyses and the remainder processed to juice as described in section 3.2.3 and 3.2.4. Chemical analyses were performed within two days, except polyphenols which were determined after two months of storage.

3.1.1. Sample Preparation

About 15-20 apples were quartered and blended with an Oster blender. Immediately three 20-25g samples were weighed in aluminum dishes for moisture determinations.

One hundred and fifty grams of the apple slurry were weighed into a 2L beaker to which 400 ml of distilled water was added and boiled for 1hr. This sample was transferred to a 1L volumetric flask, cooled, diluted to volume and filtered through ordinary cotton. Total acidity, pH and total soluble solids were performed

on the filtrate.

3.1.2. Analytical Methods and Statistical Analysis

Total moisture was determined on 20 g samples by the vacuum oven method as reported in A.O.A.C. (1975) 22.018. Results were expressed as percent moisture.

pH values were obtained using a digital type pH meter. Total acidity was determined by titrating 50 ml of juice with 0.1N NaOH to a pH end point of 8.1. Results were expressed as percent malic acid.

Total soluble solids (TSS) were determined using an Abbe table refractometer. The refractive index was corrected for temperature and converted to percent sucrose from A.O.A.C. tables.

For total polyphenols analyses, the frozen samples (-36°C) were finely grated by a Hobart mixer, equipped with grater plate in a 9 inch vegetable slicer. Grating was performed at 4°C to minimize browning of the samples.

Total polyphenolic analyses were carried out by standard methods (A.O.A.C., 1975 9.098, 9.099 and 9.100). The determinations were made on alcohol extract prepared by blending 10g of grated, frozen sample in 60 mL of 75% ethanol for five minutes. Results were expressed as percent tannic acid.

A total of three replications were performed on each of the three samples (section 3.1.1.). Therefore, for every analysis the total number of observations were nine. The means and standard deviations for each chemical component were calculated.

3.2. Filtration Process

3.2.1. Apparatus

The mobile filtration assembly was constructed on a metal frame. Housings (AP100T) were assembled with PVC pipes (schedule 80). The filtration system consisted of filters with pore sizes of 106 μm , 60 μm , 25 μm , 5 μm , 1 μm , 0.85 μm , 0.45 μm and 0.22 μm connected in series. The 106 μm , 60 μm , 25 μm , 5 μm and 0.22 μm filters were purchased from Culligan International Company, North Brooks, Illinois, whereas the 0.85 μm and 0.45 μm were purchased from Millipore Corporation, Bedford, Massachusetts, 01730. The 1.0 μm filter (DCCPY nominal rating, CUNO MICRO WYND) was purchased from AMF CUNO Division, Meriden, Connecticut. A multispeed Tri-Clover rotary pump supplied by CFPDC, Portage La Prairie was used to circulate the juice through the filtration system. Turbidity of the juice was measured with a nephelometer (DRT-100, HF instruments, 105 Healey Rd, Bolton, Ontario). A stainless steel pressure gauge was installed in the line to measure pressure. Flow rate was measured with a flowmeter from Gilmont Instruments, Inc. Great Neck, N.Y. 11021. Prior to filtration of the apple juice the entire system was sanitized by recycling 300 ppm liquid chlorine (Divex) solution for 30 minutes.

3.2.2. Filtration Assembly

Filtration studies were conducted on a pilot plant scale. A flow diagram of the filtration system is illustrated in Figure 2. The filtration assembly was divided into two units, a coarse filtration unit and a fine filtration unit. The coarse filtration unit consisted of filters with pore sizes ranging from 106 μm to

Figure 1. Pilot plant cartridge membrane filtration system utilized for filtration and sterilization of apple juice

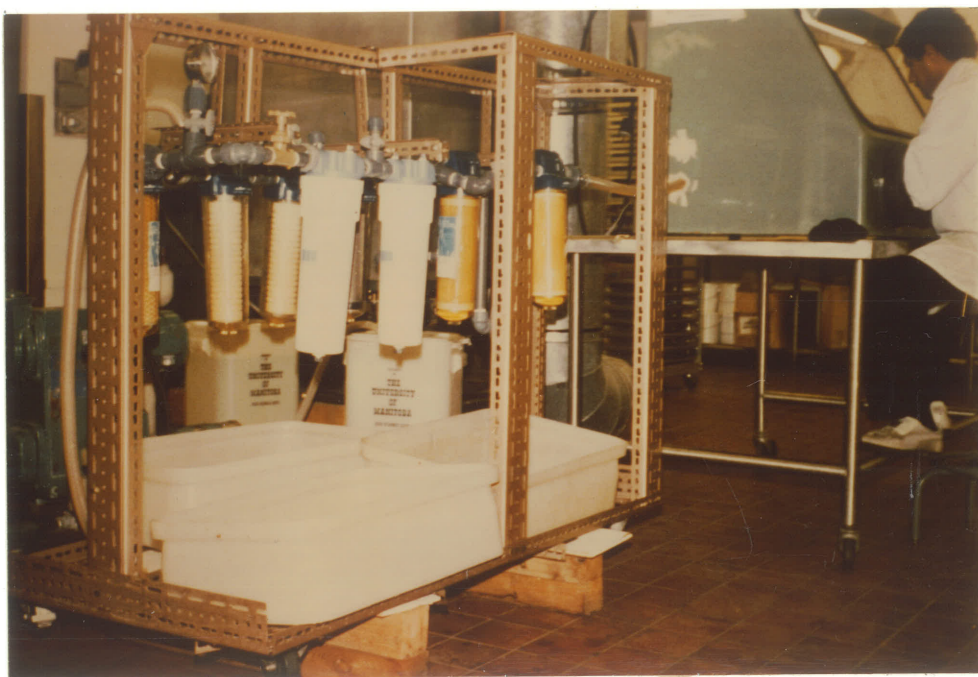
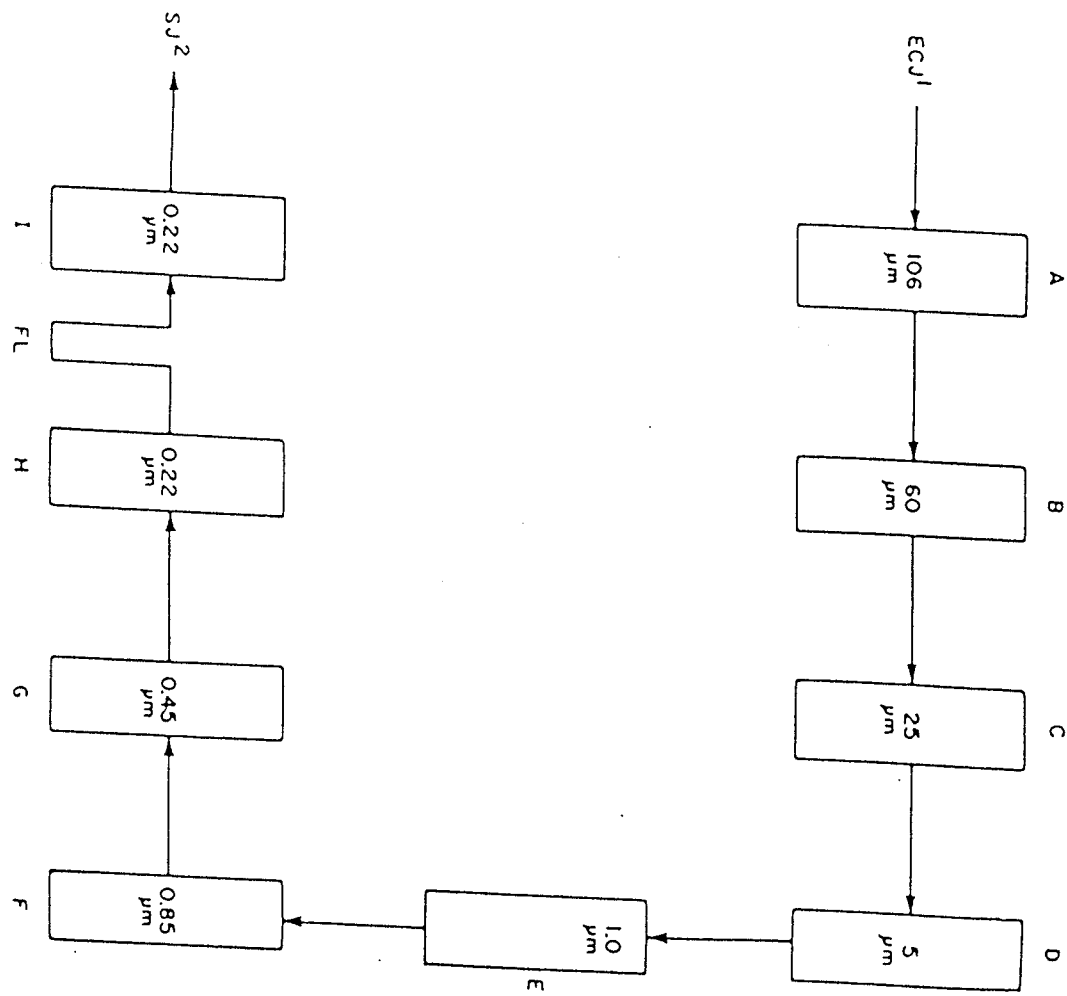


Figure 2. Flow diagram of filtration assembly



- A - E COARSE FILTRATION UNIT
- E - I FINE FILTRATION UNIT
- FL FLOW METER
- 1. ENZYME CLARIFIED JUICE
- 2. STERILE JUICE

1 μm . The purpose of coarse filtration was to remove suspended particles from the enzyme clarified apple juice and secondly, to protect the fine filtration unit from becoming clogged. The clear juice obtained after coarse filtration was further pumped through the fine filtration unit. The fine filtration unit consisted of filters with pore sizes ranging from 1 μm to 0.22 μm . The purpose of the fine filtration unit was to produce a brilliantly clear and sterile juice. The sterile juice was bottled aseptically in an ultraviolet chamber but without turning on the UV light.

3.2.3. Clarification Test

A 100 ml sample of freshly pressed apple juice was placed in a 200 ml graduated cylinder and pectinase enzyme (Clarex-P-150, Laboratory Inc. Toronto, M9W 1G6) at four concentrations, 0.05%, 0.1%, 0.15% and 0.2%, was added at room temperature and stirred gently. Separation volume was measured by noting the volume of sediment on the cylinders graduated scale after 0, 3, 6, 9 and 24 hrs. This test was performed in duplicate for each concentration of the enzyme.

3.2.4. Pectin Test (Alcohol Method)

Juice to be analyzed for pectin was mixed with 96% ethyl alcohol in a 1:1 ratio in a graduated cylinder and stirred gently. A positive pectin test is indicated by the presence of gelatinous precipitate which is formed within two minutes after mixing the juice and the ethyl alcohol. A negative pectin test is indicated by the absence of gelatinous precipitate.

3.2.5. Juice Preparation

Apples were thoroughly washed with cold water to remove all adhering dirt. Apples were visually inspected to remove partially and wholly decayed fruit and foreign debris. Before pressing, apples were crushed into small pieces with a crusher supplied by Agriculture Canada, Morden, Manitoba. Juice was extracted by a hand operated (Italian Wine Press) fruit press. To exclude debris and large particles from the extracted juice, the fruit press was lined with a nylon net. Following extraction 0.15% (W/V) pectinase was added to the cloudy juice to facilitate clarification. The enzyme treated juice was held overnight at room temperature after which the clear juice was siphoned into second container in preparation for juice filtration.

3.2.6. Filtration Process

Prior to filtration of the apple juice, the entire filtration system was sanitized by pumping liquid chlorine at a concentration of 300 ppm through the system for 30 minutes. Following sanitization, the system was washed thoroughly with cold distilled water to remove the chlorine from the system. The enzyme clarified apple juice was cycled through the coarse filtration unit to remove most of the suspended particles and to protect the final filters from becoming clogged. The total volume of juice passing through the coarse filtration system once from 106 μm to 1 μm filter constituted one cycle. After each cycle a 200 ml sample was taken and its turbidity was measured with a turbidimeter. Coarse filtration was terminated after a constant turbidity

reading was observed. Pressure was also measured after every filter during coarse filtration except the 1.0 μm filter.

The clear juice obtained after coarse filtration was then filtered through the fine filtration unit to obtain a sterile and polished juice. Pressure readings were taken after every filter except after the 0.22 μm filters for every 3.5 liters of juice collected and flow rate was measured after the 0.22 μm filter. The sterile apple juice was collected aseptically in a UV chamber in sterilized glass bottles which were previously sterilized at 170°C for 2 hours. The sterile juice was stored at -36°C until used for future analyses.

3.2.7. Samples, Analytical Methods and Statistical Analysis

For process characterization approximately 500 mL samples were collected after every filter in clear glass bottles. Samples were frozen at -36°C for analysis at a later convenient time.

Total acidity, sugar and polyphenol content were determined by the methods described in section 3.1.2. All determinations were done in triplicate. The mean and standard deviation for each chemical component analyzed were calculated.

3.2.8. Plate Counts for Yeasts and Molds in Apple Juice

During the filtration of the apple juice, samples were collected after the 0.22 μm filter in a whirl pack. Plate counts for yeasts and molds were performed immediately after the samples were collected. Plate counts were performed according to the method reported in Compendium of Methods for the Microbiological

Examination of Food, 1984 17.52. Plates were incubated at room temperature (21°C) for five days. Results were reported as yeast and mold count per mL of apple juice.

3.3. Sensory Evaluation

3.3.1. Sample Selection and Preparation

Sufficient quantities of Scotian Gold apple juice with the same lot number sold in Tetrapack containers were purchased from a local supermarket and were stored at room temperature for a period of one month. The processed juice was stored at -36°C in sterilized glass containers.

Prior to the sensory evaluation, the frozen apple juice samples were thawed overnight at room temperature. The thawed juice and the Scotian Gold control samples were refrigerated at 3-5°C until about one hour prior to the evaluation. Ten different blends of the processed apple juice were also tested. Blending was done using the Pearson square method (Appendix 1) which was based on a sugar-acid ratio of 17 (Appendix 2).

3.3.2. Panel Selection

Initially a sixteen member panel consisting of nine male and seven female graduate students and staff members of the Department of Food Science, aged 22-35, were selected for this study. Criteria for selection included availability, willingness and interest. The panelists had varying degrees of experience in sensory evaluation. Panelists were asked to rank samples of different concentrations of fructose, malic acid and tannic acid in

descending order for sweetness, sourness and bitterness respectively (Appendices 3 & 4). No statistical analysis of panelist performance was conducted. Nine panelists, five male and four female, were selected on the basis of consistent performance in the ranking of these solutions in the correct order.

3.3.3. Selection of Vocabulary

The purpose of this phase of sensory evaluation was to establish aroma and flavor (by mouth) descriptors for apple juice. Twelve apple juice samples, one from each of the ten cultivars under study and two commercial samples were tested. Panelists were provided with three samples per session and were asked to list terms which best described aroma and flavor. The evaluation sheet used is shown in Appendix 5. A total of three odor and four flavor characteristics were selected from the panelists responses as the attributes that best described the sensory characteristics present in the apple juice (Appendix 6).

3.3.4. Panel Training

The nine member panel met for ten one hour sessions over a period of three weeks to become familiar with the method of Quantitative Descriptive Analysis (QDA) (Stone et al., 1974). The scaling procedure described by Larmond (1977) was used. The scale was a 15 cm long horizontal line without anchor points. The end points were labelled as weak to strong. Each panelist recorded his or her evaluation by making a vertical line across the horizontal line that best reflected the magnitude of that parameter in the sample. Panelists were first trained for aroma

and then for flavor. During each session panelists were provided with three samples of apple juice for aroma and flavor evaluation. To assist panelists in the evaluation of apple juice appropriate references were also provided (Appendix 7). After each session the results were discussed. All panel members were encouraged to participate in the discussion with the group leader providing guidance. The process of evaluation of the apple juice and discussion was repeated until the language for flavor description of aroma and flavor was fully agreed upon by the panelists. Six descriptors two for aroma and four for flavor were agreed upon amongst the panelists (Appendix 7). Training continued until all panelists were consistent in evaluating the apple juice for each sensory characteristic.

3.3.5. Sample Presentation

The sessions were held in a sensory panel room with individual booths. Red lights were used to mask any color differences that might influence a panelists judgement. Sensory analyses were first conducted for aroma (1 week) and then for flavor (2 weeks). Two replications for each cultivar juice sample were carried out. One replicate was presented in the morning and the second during the afternoon of the same day. The order of sample presentation is shown in Appendices 8&9. All samples were coded with three digit random numbers and the order of serving for each judge was randomized to prevent the panelists from being biased. Crackers and water were available in each booth. The ballots used are shown in Figures 3 and 4.

Figure 3. Ballot used for the evaluation of aroma in apple juice

Name _____

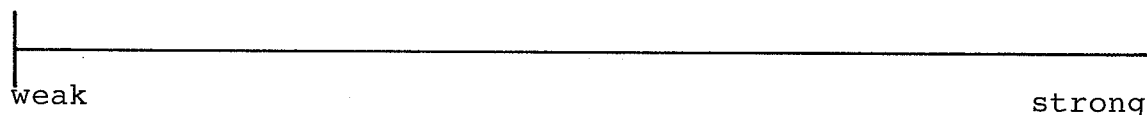
Date _____

You have been given Reference(R) samples and Apple Juice samples for odor evaluation. Take three short sniffs from the reference sample for fermented odor and replace the lid. Take three short sniffs from the apple juice samples in the order listed and mark the intensity of fermented odor of the juices in relation to the reference. Proceed with apple odor in the same way. Please comment if additional odors are detected.

Code _____

Fermented

Apple



Comments:

Figure 4. Ballot used for the evaluation of flavor in apple juice

Name_____

Date_____

You have been given apple juice samples for flavor evaluation. Please evaluate for Apple Flavor, Sweetness, sourness and Astringency. Mark vertical lines on the horizontal line and label each vertical line with the code numbers of the sample it represents. Rinse your mouth with water between each sample. Please taste the samples in the following order. Please comment if additional flavors are detected.

Code_____

Apple

|-----|
weak strong

Sweetness

Sourness

Astringency

Comments:

3.3.6. Statistical Evaluation of Sensory Data

A grid divided into 60 units was superimposed over the scaling (section 3.3.4.) line to obtain values from the QDA scale. A number between 0 and 60 could be assigned to each rating. Once the values were obtained, the data were analyzed using factorial analysis of variance. Duncan's Multiple Range test was applied to determine significant differences amongst means.

3.4. Chromatographic Analysis of Sugars and Acids in Apple Juice

3.4.1. Sample Preparation

About 15-20 mL of apple juice samples, blended juices and the reference used in sensory analysis were frozen at -36°C in clear glass bottles. These samples were later used for the determination of sugars and acids by High Performance Liquid Chromatography (HPLC). Final sample preparation was done after thawing out the frozen samples.

The thawed samples were filtered through a $0.45\text{ }\mu\text{m}$ nylon filter (Micron Separations Inc. Honeoye Falls, NY) to ensure removal of any particulate impurities that might be present. Since pigments in the juice can severely hinder the life of the analytical column, Sep-Pack C18 cartridges (Waters Associate Inc.) were used to retain these colored pigments. The Sep - Pack was placed at the end of a 10 mL graduated syringe. The C18 cartridge was first prewet with 2 mL of methanol and then flushed with 5 mL of distilled water. After this, a 3 mL sample was poured into the graduated syringe, then the first 2 mL of the sample was discarded, and the next 1 mL was collected and used for HPLC analy-

sis.

3.4.2. Apparatus

The organic acid column (Aminex Ion Exclusion HPX - 87H) and the carbohydrate column (Aminex HPX- 87P Heavy Metal), were purchased from Bio-Rad Laboratories, 32nd Griffin Ave., Richmond, Calif. 90804. Columns were placed in a temperature controlled oven and attached to a Water Associates (Water Associates Inc., Maple St., Milford, MA 01757) HPLC assembly. The HPLC assembly consisted of a solvent delivery system (model 6000A), sample injector (model U 6K), an Ultraviolet absorbance detector (model 440) with extended wavelength (214 nm) module and a differential refractometer (model R401).

3.4.3. Eluent Preparation

Water and 0.01N H_2SO_4 with 10% acetonitrile were used as eluents for sugar and acid analysis. The mobile phase was filtered through a 0.45 μm filter and degassed under vacuum prior to use. The mobile phase was held in a reservoir for sugar and acid analysis and was kept warm by placing the reservoir on a hot plate.

3.4.4. Operating Conditions

Sugar analyses were performed at a flow rate of 0.60 mL/min at 85°C while acid analyses were performed at a flow rate of 0.50 mL/min at 70°C. Recording and analysis of detector responses were conducted on a Vista 401 (Varian Instrument Group, Walnut Creek Division, 2700 Mitchell Dr., Walnut Creek, Ca. 94598).

3.4.5. Expression of Results and Statistical Analysis

The concentrations of sugars/acids in the samples were obtained by comparison of peak areas of samples to those of standard sugar/acid solutions of known concentration (4mg/mL). Results were expressed as % total sugar. Acid concentrations were expressed as % malic acid. All determinations were performed in triplicate. The mean and standard deviation for each determination were calculated.

4. RESULTS AND DISCUSSION

4.1. Moisture Content (Fruit)

The mean moisture content of the fruit for all cultivars for 1983 and 1984 are shown in Table 2. The mean moisture content ranged from $82.24\% \pm 3.17$ for PF #51 to $88.19\% \pm 0.43$ for Westland. PF #50 (SD 2.08) and PF #51 (SD 3.17) demonstrated the greatest year to year fluctuation in moisture content. These values were similar to those reported by Sharma (1984) as well as those reported in the literature from other production areas (Joslyn, 1970).

4.1.2. Total Acidity (Fruit)

Total titratable acidity expressed as percent malic acid showed considerable variation between cultivars as well as within cultivars from year to year (Table 3). Heyer #12 and Westland had the highest acidity, 1.18%, in 1984. The mean acid content varied from 0.49% to 1.09% malic acid among cultivars. The mean acid content for all cultivars was 0.73% in 1983 and 0.90% in 1984. Most cultivars had a lower acid content in 1983 as compared to 1984. All cultivars could be classified as having a high acid content (Moyer and Aitken, 1980) except PF #36 and PF #51 which had a medium acid content. These results compare well with those reported by Lopez et al., 1958 and Voho and Varo 1975.

4.1.3. Total Soluble Solids (Fruit)

The total soluble solids expressed as % sucrose of the 10 apple cultivars presented in Table 4. The mean soluble solids

Table 2. Moisture content of Manitoba grown apple and crabapple cultivars

Cultivar	1983		1984		Mean	Std. Dev.
	% Moisture	Std. Dev.	% Moisture	Std. Dev.		
Kerr	85.38	0.09	84.22	0.17	84.80	0.82
Breakey	85.58	0.14	84.62	0.15	85.10	0.68
Collet	86.33	0.10	85.52	0.07	85.92	0.57
Goodland	84.81	0.75	84.62	0.08	84.71	0.13
Heyer #12	87.33	0.03	86.69	0.61	87.01	0.45
Norland	85.96	0.04	85.28	0.07	85.62	0.34
PF #36	85.37	0.07	85.02	0.09	85.19	0.24
PF #50	87.59	0.14	84.64	0.10	86.11	2.08
PF #51	80.00	0.71	84.49	0.13	82.24	3.17
Westland	88.50	0.05	87.89	0.21	88.19	0.43

Table 3. Acid content (% Malic Acid) of Manitoba grown apple and crabapple cultivars

Cultivar	1983		1984		Mean	Std. Dev.	Classification	
	% Malic Acid	Std. Dev.	% Malic Acid	Std. Dev.				
Kerr	1.04	0.02	1.14	0.01	1.09	0.07	High Acid	
Westland	0.89	0.01	1.18	0.01	1.04	0.01	"	"
Heyer #12	0.87	0.02	1.18	0.01	1.02	0.21	"	"
PF #50	0.86	0.03	0.93	0.00	0.89	0.05	"	"
Breakey	0.74	0.01	0.92	0.01	0.83	0.13	"	"
Goodland	0.78	0.03	0.89	0.00	0.83	0.06	"	"
Collet	0.66	0.01	0.86	0.00	0.76	0.14	"	"
Norland	0.62	0.01	0.71	0.00	0.63	0.08	"	"
PF #36	0.49	0.07	0.54	0.01	0.51	0.03	Medium Acid	
PF #51	0.36	0.01	0.63	0.00	0.49	0.19	"	"

Table 4. Sugar content (% Sucrose) of Manitoba grown apple and crabapple cultivars

Cultivars	1983		1984		Mean	Std. Dev.	Classification	
	% Sucrose	Std. Dev.	% Sucrose	Std. Dev.				
PF #51	14.00	0.32	13.68	0.24	13.84	0.22	Average Sugar	
Breakey	13.37	0.38	12.91	0.30	13.14	0.32	"	"
PF #36	12.86	0.32	12.52	0.36	12.69	0.24	"	"
Norland	12.10	0.42	12.71	0.39	12.40	0.43	"	"
Goodland	11.18	0.39	12.20	0.38	11.69	0.72	"	"
Kerr	10.36	0.30	11.48	0.32	10.92	0.79	"	"
Collet	10.15	0.20	11.64	0.32	10.89	1.05	"	"
PF #50	9.28	0.35	12.40	0.39	10.84	2.20	"	"
Heyer #12	8.82	0.35	9.70	0.38	9.26	0.62	Below Average Sugar	
Westland	8.73	0.39	9.28	0.35	9.00	0.06	"	"

contents for all cultivars for two years ranged from 9.00% to 13.84%, with an overall mean of 11.47%. The mean for 1983 was 11.1% and that for 1984 was 11.8%. An established mean value for the sugar content of apple is not available. However, these results are in agreement with those reported by Lopez et al., 1958, and Voho and Varo 1975. Moyer and Aitken (1980) reported the total soluble solids of varieties from various growing areas. Hence these cultivars could be classified as average sugar and below average sugar when using their classification system.

4.1.4. Total Polyphenolic Content (Fruit)

The mean phenolic content of the 10 cultivars ranged from 0.31% to 0.53% tannic acid (Table 5). Considerable variation was observed within and between cultivars from year to year. The overall mean phenolic content for 1983 was 0.38% and that for 1984 was 0.39% tannic acid. These cultivars had higher values as compared to the literature reports (Lopez et al., 1958) However, these values are in agreement with those reported by Sharma (1984).

All crabapple varieties are considered to be astringent (Moyer and Aitken, 1980). Hence Kerr (crabapple) was selected as a reference point for this classification. Cultivars with polyphenol content equal to or greater than Kerr were described as being high in phenolics. Accordingly, all the cultivars except Goodland, Collet and Westland were classified as having a high phenolic content (Table 5).

Table 5. Phenolic content (% Tannic Acid) of Manitoba grown apple and crabapple cultivars

Cultivar	1983		1984		Mean	Std.	Classification	
	% Tannic	Std. Dev.	% Tannic	Std. Dev.				
Heyer #12	0.49	0.93	0.57	0.01	0.53	0.05	High Phenolic	
PF #51	0.33	0.02	0.41	0.41	0.45	0.17	"	"
PF #50	0.46	0.01	0.41	0.07	0.43	0.03	"	"
Norland	0.43	0.02	0.34	0.01	0.38	0.06	"	"
PF #36	0.30	0.01	0.47	0.05	0.38	0.12	"	"
Breakey	0.40	0.30	0.33	0.02	0.36	0.05	"	"
Kerr	0.38	0.02	0.35	0.01	0.36	0.02	"	"
Collet	0.37	0.03	0.30	0.01	0.33	0.05	Medium Phenolic	
Goodland	0.35	0.03	0.30	0.01	0.32	0.03	"	"
Westland	0.32	0.01	0.30	0.30	0.31	0.01	"	"

4.2. Filtration Process of Apple Juice

4.2.1. Apple Juice Clarification With Pectinase

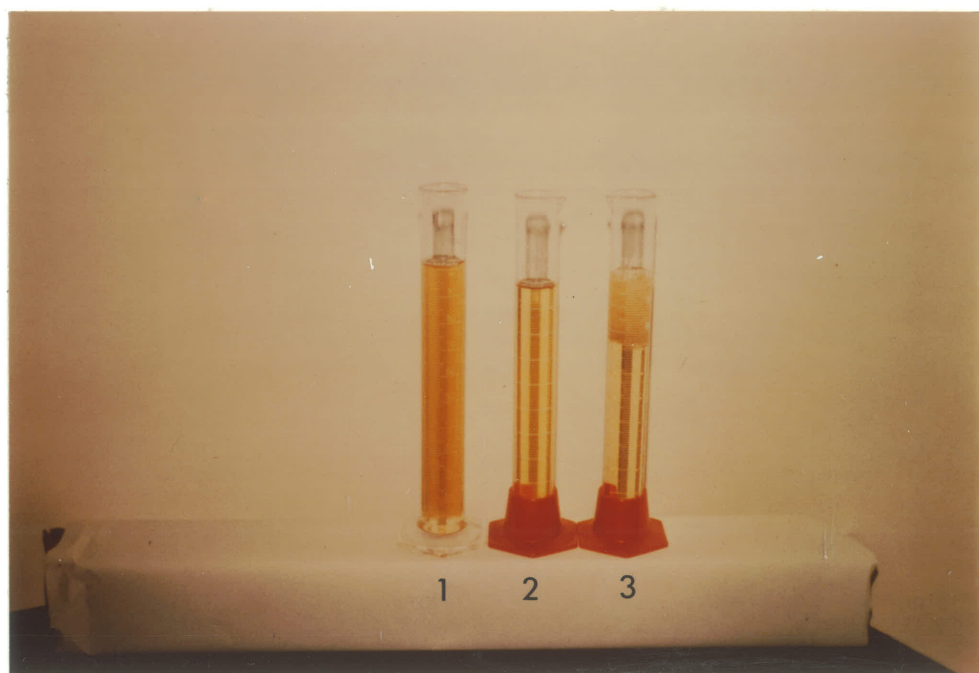
Moyer and Aitken (1980) suggested that tests be carried out to establish proper enzyme concentration needed to clarify apple juice, because of variables such as pH, temperature, enzyme concentration and length of time which are involved in enzyme clarification. Hence, during preliminary studies four different enzyme concentrations were tested at room temperature (Table 6). Maximum separation volume was achieved with 0.15% enzyme treated juice as compared to 0.05% and 0.1%. The 0.2% enzyme treated juice had a similar separation volume to 0.15%, which indicated that the enzyme was in excess. The optimum enzyme concentration therefore was determined to be 0.15%. The time required for almost complete depectination was observed after 9 hours for the 0.15% and 0.2% enzyme treated juice. This was confirmed by a negative alcohol test, indicated by the absence of a gelatinous precipitate after 60 minutes (Figure 5). This test is based on the fact that pectin residues containing 8 to 10 galacturonic acid units are insoluble in ethyl alcohol and combine with water to precipitate as a gel (Baumann, 1981). The actual quantity of pectinase required for depectination cannot be compared with reported values since the pectin content varies with varieties, growing area, time of harvest and length of storage. However, these results are in agreement with using 0.1% pectinase and 0.5% to 0.6% bentonite as recommended by Mian and Bhatti (1969).

4.2.2. Filtration Efficiency of Apple Juice

Table 6. Effect of enzyme concentration on the rate of depectination of apple juice at room temperature

Time (Hrs)	Concentration of Enzyme (w/v)			
	0.05%	0.1%	0.15%	0.20%
0	00.00	00.00	00.00	00.00
3	94.60	95.14	95.80	95.80
6	95.20	95.70	96.40	96.40
9	96.60	96.10	97.00	97.00
24	95.80	96.10	97.20	97.20

Figure 5. Alcohol test for detection of pectin in clarified apple juice



1. Fresh apple juice (no pectinase).
2. Apple juice clarified with 0.15% pectinase + 95% ethyl alcohol.
3. Fresh apple juice + 95% ethyl alcohol.

The filtration efficiency of apple juice was conducted on juice processed from the cultivar PF #51. This test determines the readiness of a juice for fine membrane filtration or if it requires further refiltration through the coarse membrane system. Enzyme clarification was found to be an important factor in improving the efficiency of the coarse filtration system. It was observed that the 0.15% enzyme treated juice required half the number of recycles (6 recycles) to obtain a constant turbidity reading as compared to 0.1% enzyme treated juice (Figure 6).

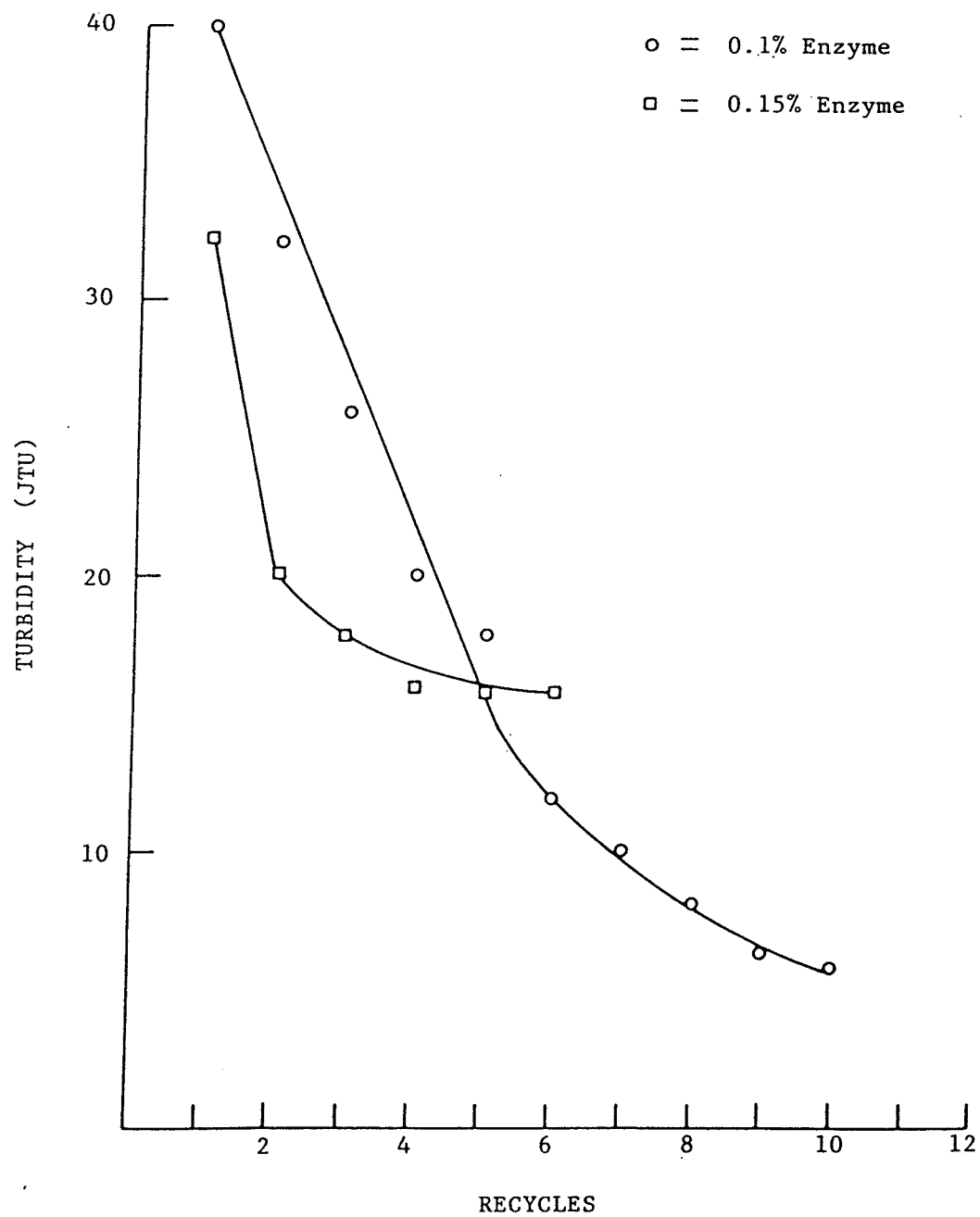
4.2.3. Recycling of Apple Juice

The decrease in turbidity readings (Figure 7). were used to monitor the decrease in suspended particles in apple juice throughout the coarse filtration procedure. Steady turbidity value was observed after the 3rd recycle and recycling was terminated after the 4th recycle. This indicated that the filters utilized for coarse filtration were unable to remove the remaining suspended particles due to their size. Recycling was necessary to reduce the potential accumulation of suspended particles on the fine 0.22 μm membrane filtration system and thereby prolong its use.

4.2.4. Filter Performance During Filtration

The purpose of the cartridge membrane filtration system was to remove as much of the suspended particulate material and microorganisms as possible. The membranes used in this system were selected with a narrow range of pore size differential. This would allow a more even distribution of suspended solids through-

Figure 6. Filtration efficiency of apple juice



out all the membranes and eliminate over loading of one membrane. Hopefully this design would permit a more continuous filtration process. Sharma (1984) recommended that turbidity measurements would be useful to monitor the quantity of suspended solids removed by each membrane. This procedure would also permit an operator to assess when the membrane became overloaded and should be replaced in the system.

In this study juice was collected after each membrane and the turbidity measured. The data (Figure 8) suggested that the system achieved its intended purposes. The maximum load of suspended solids was removed by the 106 μm filter. This filter was designed to protect the finer filters ranging from 60 μm to 1 μm and the data illustrates that protection was achieved. The quantity of suspended solids removed by each of the membranes from the 60 μm to the 1 μm membrane indicates that the load was evenly distributed among them. The differential between the 25 μm and 5 μm membranes was slight indicating that perhaps the 25 μm cartridge is not necessary.

The coarse membrane system (one cycle) did not remove as much of the suspended solids (less than 1 μm) as needed and the juice was not allowed to pass directly to the fine filtration system (0.85 μm to 0.22 μm). This juice was recycled through the coarse filtration system several times in order to remove more of the small diameter particles (less than 1 μm) with the larger pore membranes. The success of this method can be seen in the reduction of turbidity between the 1 μm and the 0.85 μm mem-

Figure 7. Degree of turbidity on recycling

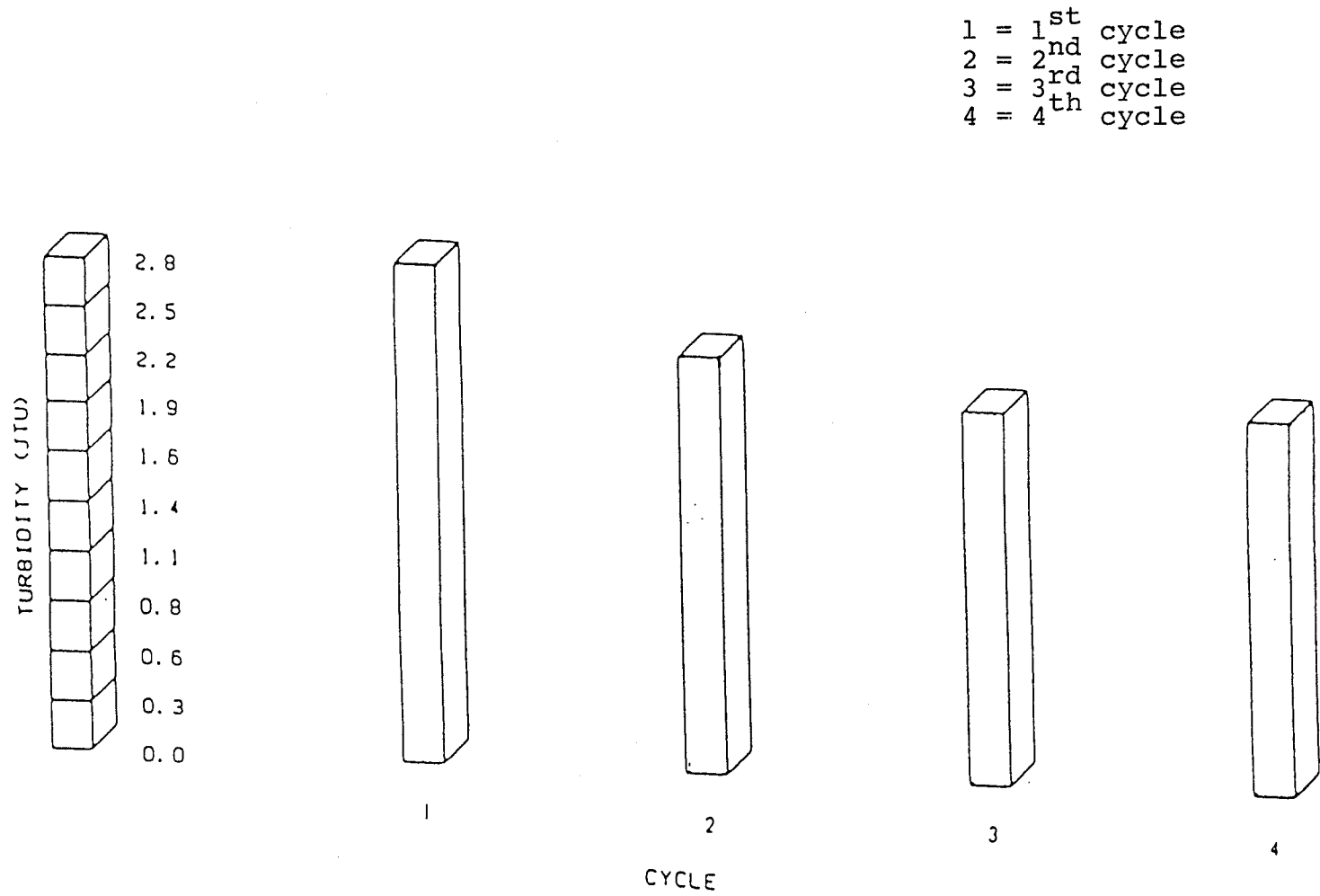
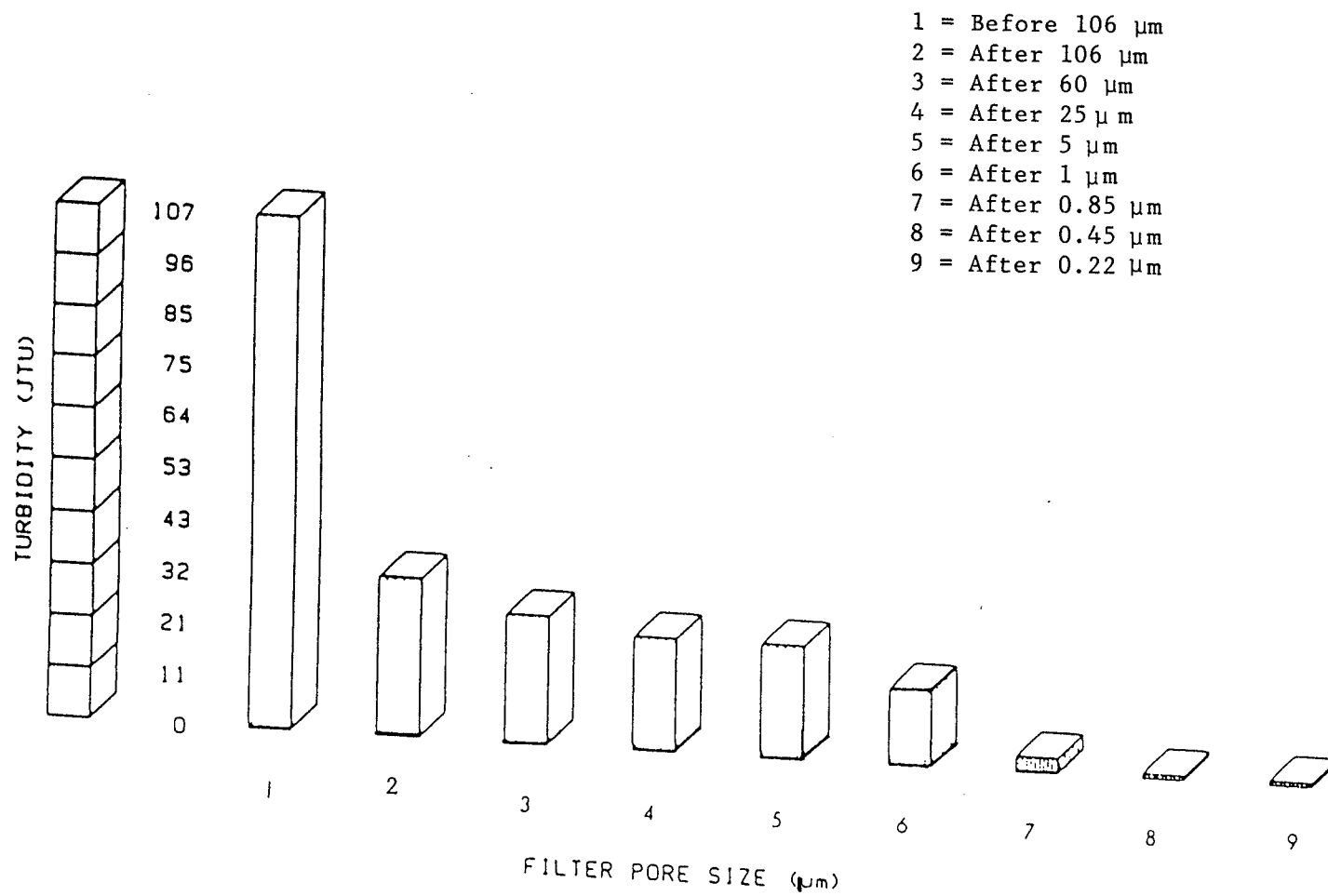


Figure 8. Filter performance during filtration



brane (Figure 8). If this had not been carried out the 0.85 μm membrane would be greatly overloaded with solids and filtration efficiency would have decreased.

The comparison of turbidity (Table 7) showed that the commercial apple juice had higher turbidity values compared to those of the test juice. This was due to the fact that commercial apple juice was filtered up to the 1.0 μm limit and then heat treated (pasteurized), whereas the test juice had a lower turbidity value because it was filtered down to a 0.22 μm limit.

Microbiological assays were carried out on the final product after the juice passed through the 0.22 μm filters for all ten cultivars in 1984. Plate counts for yeast and molds are presented in Table 8. A very small number of organisms (3 to 18 per ml of juice) were detected in the first six juice samples. This problem was attributed to the plumbing system between the last 0.22 μm filter and the collection port in the UV chamber. Repeated attempts to sterilize the entire cartridge filtration assembly with 300 ppm chlorine failed to achieve complete sterilization. Following the filtration of the juice from the PF #50 cultivar the previously mentioned plumbing system was redesigned to a single straight flow plastic hose. This assembly allowed for complete sterilization and the remaining juice samples (Table 8) had no detectable yeasts and molds.

Reeves (1983) observed that cartridge membranes permit passage of microorganisms under high flow rates and pressures and that this could be caused by distortion of the membrane pores and

Table 7. Mean turbidity value for apple juice

Apple Juice	Turbidity (JTU)
Brand A	3.00
Brand B	1.30
Brand C	6.20
Test Juice	0.30

Table 8. Plate count for yeast and mold in apple juice.

Cultivar	Yeast and Mold per mL of Juice
PF #51	18
Norland	12
PF #50	10
Goodland	06
Westland	05
Heyer #12	03
PF #36	00
Collet	00
Kerr	00
Breakey	00

the microorganisms. However his observations were based on the use of a 0.65 μm membranes. Two 0.22 μm membranes were utilized in this system therefore it is unlikely that the above problem was caused by membrane failure. PVC piping was utilized in the first delivery system and it was probable that microorganisms may have become trapped in the internal threading of this system. The results obtained after this system was replaced support this position.

4.2.5. Flow Rate and Pressure

The flow rate and pressure values during fine filtration are presented in Table 9. During the start of each run, pressure was observed to increase after each of the filters. This was probably caused by fluctuations in flow. After equilibrium was achieved, pressure and flow rate declined progressively until 11.25 liters of juice had been collected. At this time pressure increased in each of the filters while flow rate continued to decrease. The volume of juice obtained from each cultivar was not sufficient to collect further data. The direct relationship between pressure and flow rate at the beginning could be explained as follows: Pressure data was not collected before the filter because of the way the filtration system was built. Pressure was probably increasing on the 1 μm filter but this was undetected and caused the flow to decrease within the system. Particle build up within the 0.8 μm and 0.45 μm filters became sufficient after 11.25 liters was collected to cause an increase in pressure after 15 liters.

Table 9. Flow rate and pressure during fine filtration of apple juice

Volume of apple juice (ml)	Filter Size (μm)			Flow rate	
	1.0	0.85	0.45	ml/min	l/hr
		kPa			
3750	296.00	287.60	105.30	350	21.0
7500	290.50	282.70	102.90	320	19.20
11250	264.50	261.00	89.60	280	16.80
15000	282.70	274.40	91.00	254	15.24

¹Pressure Expressed as kPa

²Flow rate expressed as ml/min

The performance of the filters is dependent upon the effectiveness of clarification and pre-filtration procedures. Commercial flow rates measured after the 0.65 μm filter sheet are 140-250 L/h per 600 mm sheet or 60-100 L/h per 400 mm sheet (Reeves, 1983). These values are not in agreement with the experimental flow rate values because flow rate (Table 9) was measured after the 0.22 μm filter.

4.2.6. Effect of Filtration on the Chemical Composition of Apple Juice

This study was undertaken to determine the chemical changes which occur during the processing operation because processed apple juice is considered inferior to the freshly pressed juice or apple cider. Information available on apple juice as a result of filtration is limited. With this filtration system a small decrease in the acid, sugar and phenolic contents were observed as the filter pore size decreased (Table 10). The reduction in total acidity could be explained by the ionic interaction between the acids and the suspended particles which were removed during filtration. This is mainly due to the pH of apple juice which is low enough to maintain the ionic nature of the acids in apple juice.

The method to determine sugar content was based on refractive index. Hence the observed decrease in the sugar content of apple juice could not be attributed to filtration because the soluble components are not removed during filtration. It is possible that suspended particles did interfere with the refractive index read-

Table 10. Chemical changes observed in apple juice (Collet) during the filtration process

Filter Pore Size μm	Acid (% Malic Acid)		Sugar (% Sucrose)		Phenolics (% Tannic Acid)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Before 106	0.76	0.32	11.40	0.06	0.08	2.60
After 106	0.74	0.06	11.13	0.04	0.07	0.98
After 60	0.74	0.15	11.13	0.04	0.07	0.98
After 25	0.74	0.11	11.11	0.03	0.07	0.96
After 5	0.73	0.05	11.13	0.03	0.07	0.93
After 1	0.73	0.10	11.15	0.13	0.08	0.97
After 0.8	0.73	0.05	11.15	0.11	0.06	1.97
After 0.45	0.72	0.06	11.13	0.03	0.06	2.61
After 0.22	0.71	0.15	10.27	0.04	0.06	0.97

ings and this interference was reduced as the particles were removed by filtration. The decrease in the phenolic content upon removal of suspended particles was expected. Neubert (1942) reported that phenolic compounds were among the constituents of suspended particles present in apple juice.

4.3.1. Total Acid and pH in Apple Juice

The total acid content in the filtered apple juice (1983 and 1984) is presented in Table 11. The total acid ranged from 0.34% (Norland) to 0.87% (Heyer #12). Seasonal effects on total acid content within cultivars ranged from 0.01% (Breakey) to 0.40% (Goodland). In general climatic conditions in 1984 produced considerably more acidic juices averaging 0.72 in 1984 and only 0.43 in 1983.

The pH values of the juice from the different cultivars ranged from 3.43 for Kerr to 4.15 for PF #51 (Table 12). This variability, approximately 0.7 pH units, was greater than that caused by seasonal differences (0.09 pH units for Kerr to 0.48 for Norland). Apple juice pH values are very important during thermal sterilization processes. Pederson and Beattie (1943) suggested that apple juice containing a high hydrogen ion concentration may be pasteurized at lower temperatures because pasteurization is based on time, temperature and pH. In general as pH increased, acidity decreased because following harvest there was a decline in total acidity. For example, the pH values for PF #51 and Norland were 4.15 and 4.06, which had corresponding total acidities of 0.37% and 0.34% respectively. It is presumed that

Table 11. Acid content (%Malic Acid) of apple and crabapple juice

Cultivar	1983		1984		Mean	Std. Dev.
	% Malic Acid	Std. Dev.	% Malic Acid	Std. Dev.		
Kerr	0.64	0.06	1.01	0.00	0.82	0.26
Breakey	0.45	0.00	0.44	0.00	0.45	0.01
Collet	0.30	0.00	0.70	0.03	0.50	0.28
Goodland	0.32	0.00	0.88	0.03	0.60	0.40
Heyer #12	0.83	0.03	0.91	0.06	0.87	0.06
Norland	0.18	0.00	0.50	0.06	0.34	0.23
PF #36	0.20	0.00	0.39	0.03	0.30	0.13
PF #50	0.49	0.02	0.81	0.00	0.65	0.23
PF #51	0.27	0.01	0.47	0.00	0.37	0.32
Westland	0.60	0.00	1.05	0.06	0.83	0.32

Table 12. pH of apple and crabapple juice

Cultivar	1983		1984		Mean	Std. Dev.
	pH	Std. Dev.	pH	Std. Dev.		
Kerr	3.37	0.05	3.50	0.00	3.43	0.09
Breakey	3.77	0.06	3.62	0.03	3.70	0.11
Collet	3.72	0.03	3.45	0.05	3.60	0.19
Goodland	3.86	0.06	3.40	0.00	3.63	0.32
Heyer #12	3.53	0.02	3.36	0.03	3.45	0.12
Norland	4.40	0.00	0.02	3.72	4.06	0.48
PF #36	4.30	0.05	3.78	0.03	4.04	0.37
PF #50	3.71	0.03	3.43	0.03	3.57	0.20
PF #51	4.43	0.02	3.87	0.00	4.15	0.34
Westland	3.72	0.03	3.30	0.00	3.51	0.30

acids along with sugars serve as substrates for respiration.

The pH and total acid content of the juices are in general accord with those reported by Lopez et al. (1958) and Voho and Varo (1975). The total acid content of the juice is important especially in terms of blending. Apples which have a high acid content are useful for blending with apples which have a low acid contents, especially those prepared from long term stored apples. During storage acid content decreases because it serves as a substrate for respiration (Smock and Neubert, 1950).

4.3.2. Total Sugar and Total Phenolic Contents in Apple Juice

The mean sugar content for the cultivar juices ranged from 8.57% to 11.93% sucrose (Table 13). Considerable variation was observed between cultivars as well as between seasons (within juices). Seasonal differences were especially evident for Brea-key (2.65 S.D) and Goodland (2.42 S.D). Juice from Manitoba grown apples had lower sugar content as compared to juice made from Swiss, Finnish and Virginia apples (Poll 1981, Voho and Varo 1975, and Lopez et al. (1958).

The phenolic contents of juice samples from the different apple cultivars are shown in Table 14. The mean phenolic content varied from 0.05% (Norland) to 0.17% (PF #36) tannic acid. There was a three fold decrease in the phenolic content of juice as compared to that of the apple fruit. This decrease was expected and was due to the removal of phenolic compounds along with suspended particles during filtration. Phenolic compounds of apple juice have been established as one of the constituents of the

Table 13. Sugar content (% Sucrose) of apple and crabapple juice

Cultivar	1983		1984		Mean	Std. Dev.
	% Sugar	Std. Dev.	% Sugar	Std. Dev.		
Kerr	11.31	0.07	12.55	0.04	11.93	0.88
Breakey	10.82	0.04	7.07	0.10	8.95	2.65
Collet	9.44	0.04	11.06	0.06	10.25	1.15
Goodland	8.98	0.08	12.40	0.04	10.70	2.42
Heyer #12	11.27	0.07	8.50	0.08	9.90	1.96
Norland	8.44	0.04	10.50	0.06	9.47	1.46
PF #36	11.62	0.10	10.94	0.10	11.28	0.48
PF #50	10.77	0.06	11.44	0.07	11.11	0.47
PF #51	9.62	0.09	11.30	0.04	10.46	1.19
Westland	8.83	0.04	8.31	0.04	8.57	1.19

Table 14. Phenolic content (% Tannic Acid) of apple and crabapple juice

Cultivar	1983		1984		Mean	
	% Tannic Acid	Std. Dev.	% Tannic Acid	Std. Dev.	% Tannic Acid	Std. Dev.
Kerr	0.06	0.00	0.09	0.05	0.08	0.02
Breakey	0.18	0.00	0.07	0.01	0.13	0.07
Collet	0.04	0.00	0.08	0.00	0.06	0.02
Goodland	0.06	0.02	0.11	0.00	0.09	0.04
Heyer #12	0.23	0.01	0.09	0.01	0.16	0.10
Norland	0.05	0.00	0.05	0.00	0.05	0.00
PF #36	0.17	0.01	0.18	0.01	0.17	0.00
PF #50	0.10	0.04	0.10	0.00	0.10	0.00
PF #51	0.06	0.00	0.06	0.01	0.11	0.02
Westland	0.16	0.00	0.06	0.01	0.11	0.07

suspended particles of juice (Neubert, 1942).

4.3.3. Sugar-Acid Ratio of Apple Juice from Manitoba grown Apple and Crabapple Cultivars

The sugar-acid ratios of juice samples from the different cultivars are shown in Table 15. Large variations in sugar-acid ratios were observed within and between the juices in 1983 and 1984. The sugar-acid ratios of the different juices were higher in 1983 than in 1984. This variation reflected the unique weather and growing conditions on the Prairies. Sugar-acid ratio is important in evaluating apple quality, especially in a juice (Poll, 1981). Poll (1981) reported that a ratio of 15-18 provides an ideal balance, with 12-15 being too sour and 18-23 as being too sweet. Accordingly juice from Kerr, Westland and Heyer #12 could be considered as being too sour, while that from PF #51, PF #36, Collet, Norland and Goodland could be considered as being too sweet. Only Breakey and PF #50 seemed to have the acceptable sugar-acid ratio. It should be noted that all commercial apple juices are blended (Moyer and Aitken, 1980). Hence a proper blending procedure could permit the utilization of the juice from all the cultivars tested for the production of acceptable apple juice.

4.3.4. Analysis of Sugars in Apple Juice by HPLC

A study was conducted to separate and identify the sugars in apple juice. Results of sugar analyses for 1983 and 1984 by HPLC are summarized in Table 16., and a typical chromatogram is shown in Figure 9. Raw data for 1983 and 1984 are presented in Append-

Table 15. Sugar-Acid ratio of apple juice from Manitoba grown apple and crabapple cultivars

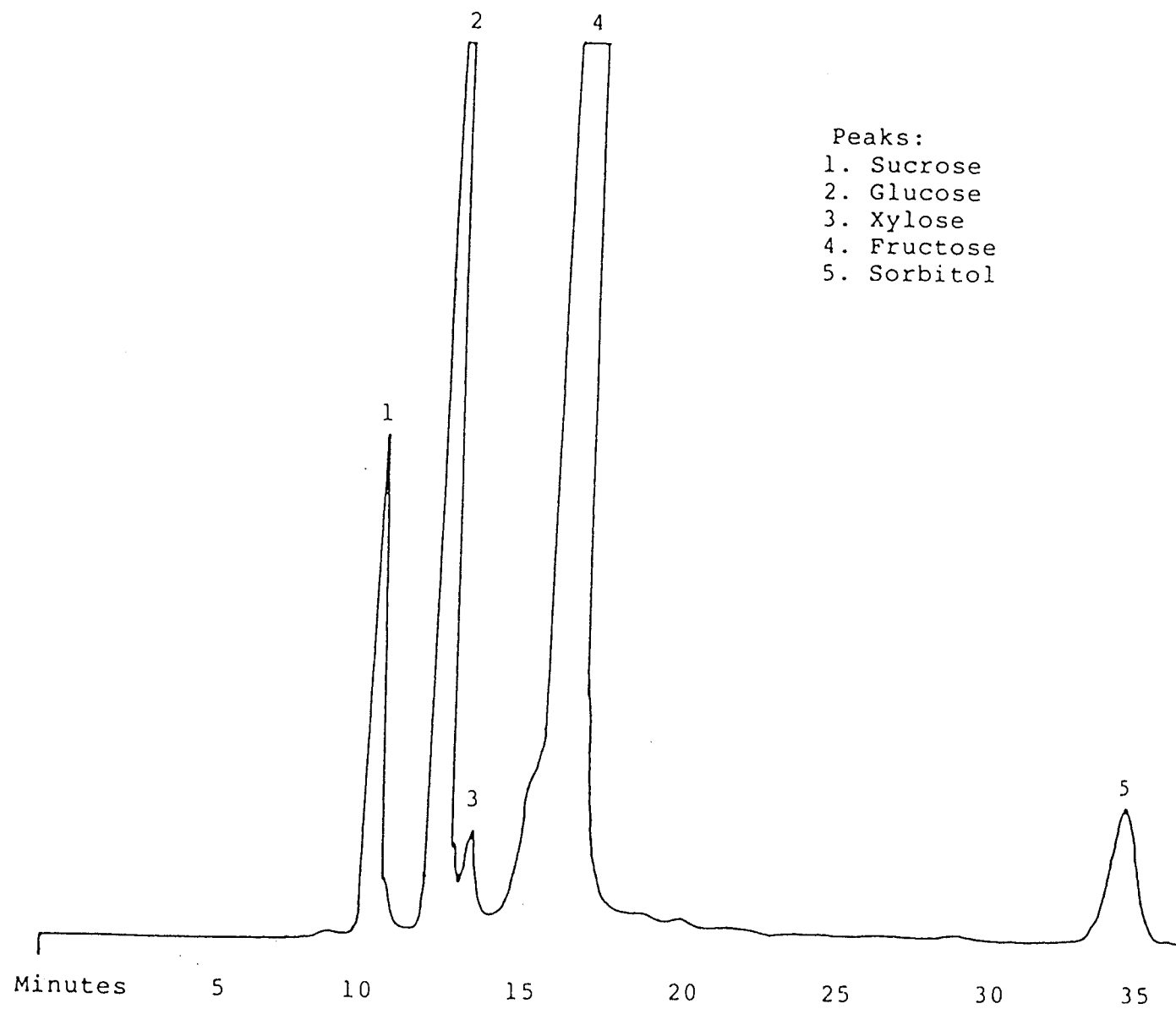
Cultivar	1983	1984	Mean S/A Ratio	Std. Dev.
	S/A ¹ Ratio	S/A ¹ Ratio		
Kerr	17.80	12.40	15.10	3.82
Breakey	23.52	16.07	19.80	5.23
Collet	31.56	15.80	23.68	11.14
Goodland	28.77	14.17	21.47	10.32
Heyer #12	13.57	9.35	11.46	3.00
PF #36	58.10	28.05	43.07	21.24
PF #50	21.98	14.12	18.05	5.60
PF #51	35.63	24.05	29.84	8.20
Westland	14.72	7.91	11.31	4.81

¹S/A = Sugar-Acid Ratio

Table 16. Sugars in apple juice (1983 & 1984) as determined by HPLC

Cultivar	% Sucrose		% Glucose		% Fructose		% Sorbitol		% Xylose		% Total Sugar
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Kerr	1.01	0.34	2.84	0.03	5.14	0.62	0.40	0.00	0.01	0.00	9.40
Breakey	1.08	0.18	1.57	0.03	6.67	0.27	0.51	0.00	0.09	0.03	9.92
Collet	0.50	0.13	1.44	0.17	6.32	1.52	0.35	0.05	0.12	0.01	8.73
Goodland	0.88	0.77	1.60	0.14	5.80	1.45	0.35	0.05	0.06	0.01	8.69
Heyer #12	0.36	0.38	1.63	0.33	5.39	0.37	0.30	0.00	0.07	0.03	7.75
Norland	1.03	0.06	1.28	0.00	5.07	1.00	0.37	0.05	0.09	0.00	7.84
PF #36	0.69	0.02	1.79	0.43	5.02	0.63	0.33	0.02	0.09	0.03	7.92
PF #50	0.53	0.43	1.40	0.13	5.16	1.60	0.25	0.00	0.03	0.00	7.12
PF #51	1.08	0.74	2.08	0.04	4.30	1.10	0.32	0.04	0.02	0.00	7.80
Westland	0.21	0.01	1.40	0.27	4.56	0.38	0.24	0.14	0.02	0.00	6.43

Figure 9. Typical HPLC chromatogram of sugars in apple juice (Collet, 1984)



ices 10 and 11.

Fructose was the major sugar component in the juice samples with smaller amounts of glucose, sucrose, sorbitol and xylose also being identified. The concentration of fructose ranged from 4.30% (PF #51) to 6.67% (Breakey). Fructose values may be an inflated estimate due to the shoulder on the fructose peak (Figure 9). With the isolation procedures used arabinose was difficult to separate as it had a retention time similar that of to fructose. Qualitative identification of arabinose by thin layer or paper chromatography was not carried out. The high concentration of fructose masked the presence of arabinose but the shoulder may be an indication that this sugar was actually present. Whiting (1970) and Sharma (1984) detected trace amounts of arabinose in apples. However, the fructose range is comparable to that reported by Ryan (1972) (4.29% to 6.45%) and Shaw and Wilson (1982) (6.7%).

Glucose values ranged from 1.40% to 2.84%. Shaw and Wilson (1982) and Ryan (1972) reported that glucose ranged from 1.72% to 3.93% in commercial apple juices. Sucrose concentrations ranged from 0.21% to 1.08%. This range is low as compared to 0.65% to 2.40% reported by Ryan (1972) and 1.4% reported by Shaw and Wilson (1982). The reason for these low sucrose concentrations could be due to cultivar and regional differences. These differences could also be due to hydrolysis of sucrose which could increase the concentration of glucose and fructose. Ryan (1972) observed lower sucrose concentration in Canadian apple juice and concluded that this may be due to processing conditions.

Sugar alcohols such as sorbitol occur naturally in many fruits of the family Rosaceae. Some fruits in this family include apples, pears, and plums. Richmond et al. (1981) reported that sorbitol plays a major role in translocation of carbohydrates to the developing fruit, and during low temperature storage it is believed that fructose is reduced to sorbitol. Shaw and Wilson (1982) reported that sorbitol contributes to the flavor of the fruit. The average sorbitol content ranged from 0.24% to 0.51%. These results are in agreement with Shaw and Wilson (1982) who found 0.25% sorbitol in commercial apple juice. Ryan (1972) on the other hand, reported values of 0.57% to 1.67% in Canadian apple juice. Xylose was present in trace amounts ranging from 0.1% to 0.12% . Whiting (1970) detected 0.05% xylose in apple juice. However, the relative proportion of sugar concentrations in apple juice from Prairie grown cultivars are similar to those reported in commercial apple juice.

4.3.5. Organic Acid Determination in Apple Juice by HPLC

Identification of each organic acid was based on retention times as compared to standards. Malic and quinic acids were the most abundant organic acids present in the juice sample from different cultivars. Galacturonic and citric acids were also present in smaller amounts. Concentrations of the individual organic acids are listed in Table 17. A typical chromatogram of the separation of organic acids in apple juice sample is shown in Figure 10. Raw data for 1983 and 1984 are presented in Appendices 12 and 13.

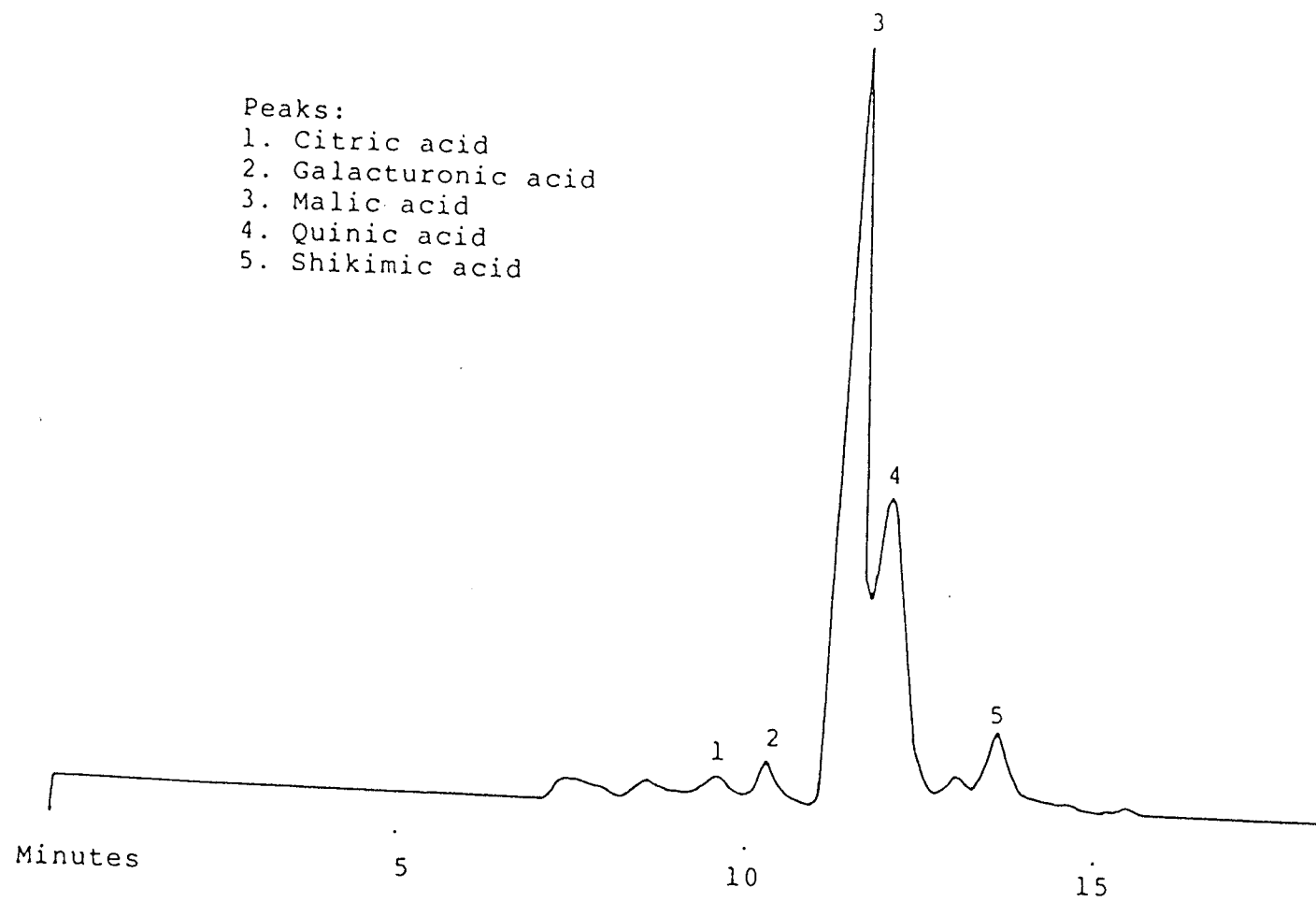
Table 17. Organic acids in apple juice (1983 & 1984) as determined by HPLC

Cultivar	% Citric		% Galacturonic		% Malic	% Quinic ¹		% Total Acid	
	Mean	Std. Dev.	Mean	Std. Dev.		Mean	Std. Dev.		
Kerr	0.02	0.00	0.11	0.02	0.90	0.31	0.47	0.01	1.50
Breakey	0.03	0.01	0.08	0.00	0.91	0.21	0.51	0.07	1.53
Collet	0.02	0.01	0.12	0.02	0.80	0.06	0.65	0.02	1.59
Goodland	0.01	0.00	0.11	0.04	0.77	0.05	0.55	0.00	1.44
Heyer #12	0.05	0.01	0.09	0.00	1.00	0.05	0.46	0.03	1.60
Norland	0.02	0.00	0.09	0.00	0.56	0.03	0.50	0.02	1.17
PF #36	0.04	0.02	0.09	0.01	0.67	0.43	0.39	0.01	1.19
PF #50	0.03	0.02	0.04	0.02	0.95	0.12	0.58	0.01	1.60
PF #51	0.01	0.00	0.03	0.02	0.52	0.13	0.45	0.02	1.01
Westland	0.02	0.00	0.05	0.01	0.74	0.50	0.38	0.02	1.19

¹Not present in 1983 Apple Juice

Figure 10. Typical HPLC chromatogram of organic acids in apple juice (Collet, 1984)

- Peaks:
1. Citric acid
 2. Galacturonic acid
 3. Malic acid
 4. Quinic acid
 5. Shikimic acid



Variation in the individual organic acid concentrations was observed between cultivars and between seasons (Table 17 and Appendices 12 and 13). Malic acid content ranged from 0.52% to 1.0% and the quinic acid content varied from 0.38% to 0.65%. Values for malic and quinic acid were in fair agreement with those reported by Ryan (1972). However, quinic acid was not detected in the juice produced in 1983. The reason for quinic not being found in the 1983 juice samples is not known, but could be due to the growing season or to conditions of storage, however the latter did not change from 1984. Galacturonic acid was present in very small concentrations ranging from 0.03% to 0.11% and only trace quantities of citric acid were detected.

4.3.6. Comparison of Official and HPLC Methods for the Determination of Total Sugar and Acid Content in Apple Juice

Results of total sugar contents by the Official and HPLC methods are presented in Tables 13 and 16 respectively. Both methods used refractive index measurements to estimate sugar concentration. The mean total sugar content of 10.26% determined by the official method was higher than the mean total sugar content of 8.16% determined by the HPLC method. The lower values determined by the HPLC method are believed to result from elimination of interfering substances after extensive clarification of the samples. It could also be due to the difference in sensitivity of the refractive index measurement. This indicated that the sensitivity of the refractive index detector used in chromatographic analysis was greater compared to the sensitivity of the human

eye used in the official methods. These results agree with those reported by Damon and Pettitt (1980). They observed a similar trend, that is lower values for sugars by HPLC as compared to official methods for molasses. Since the HPLC method is a specific method measuring each of the different sugars, the total sugar content determined by the HPLC probably reflects more accurately the true composition of sugars present in apple juice. Linear regression analysis showed a significant ($p=.01$) positive correlation ($r=.835$) between the two methods (Figure 11).

The acid content determined by the official and HPLC methods are shown in Tables 11 and 17. The total acid content determined by the HPLC method (0.78% malic acid) was higher than the official method (0.57% malic acid). This was mainly due to two different procedures involved in sample preparation and calculation of the concentration. In section 3.1.2. acidity was determined by titration and the results were expressed as percent malic acid. However, in the case of HPLC analysis acidity was measured by ultraviolet absorption at 214nm and concentration measured as percent malic acid based on the response factor and total peak area. Linear regression analysis of total acid content showed a significant ($p= .01$) correlation ($r= .742$) between the two methods (Figure 12).

4.4. Sensory Evaluation of Apple Juice

4.4.1. Aroma Evaluation of Apple Juice

Aroma and taste are the most important quality factors of

Figure 11. Comparison of sugar analysis in apple juice by Official and HPLC methods

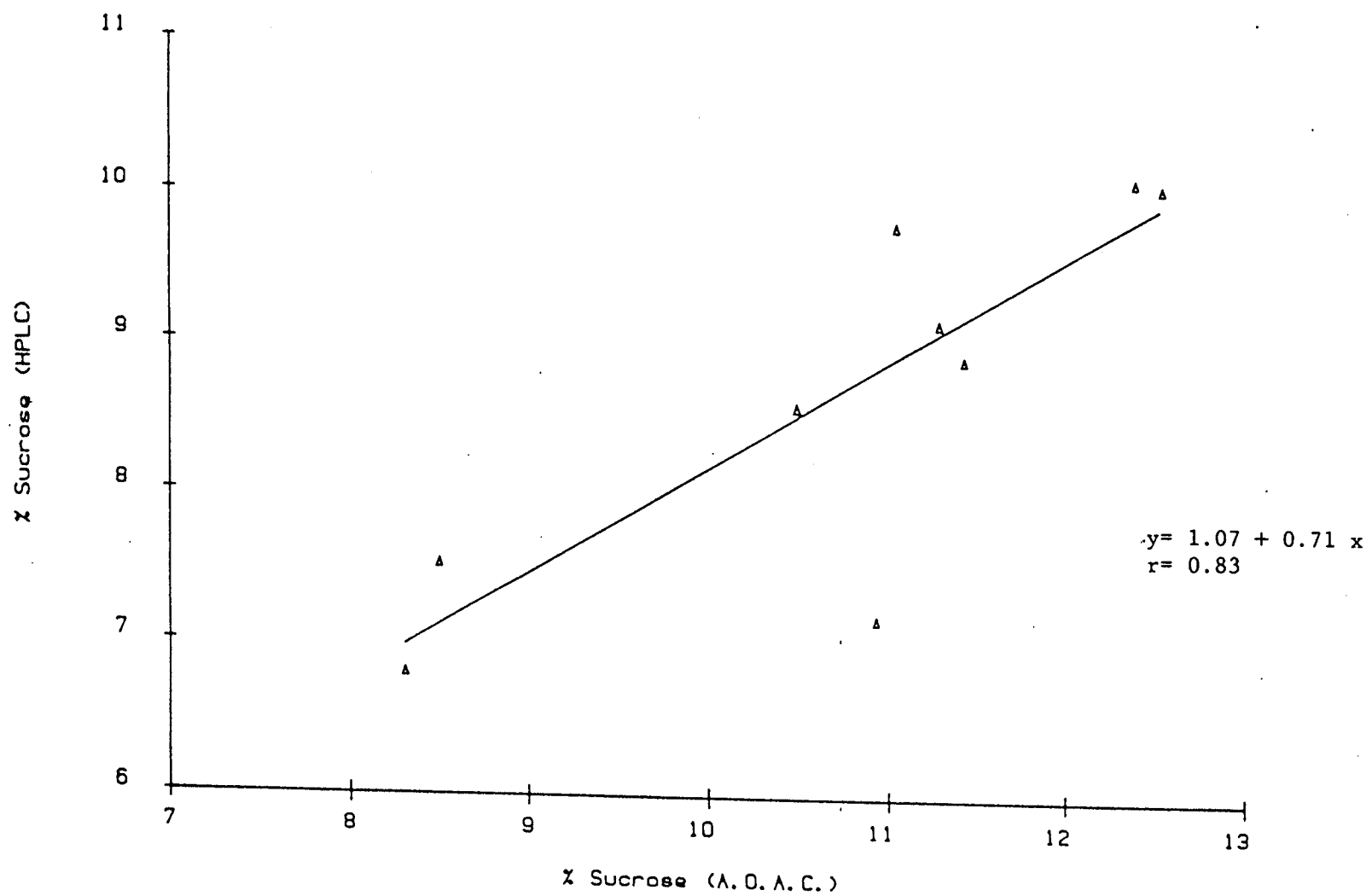
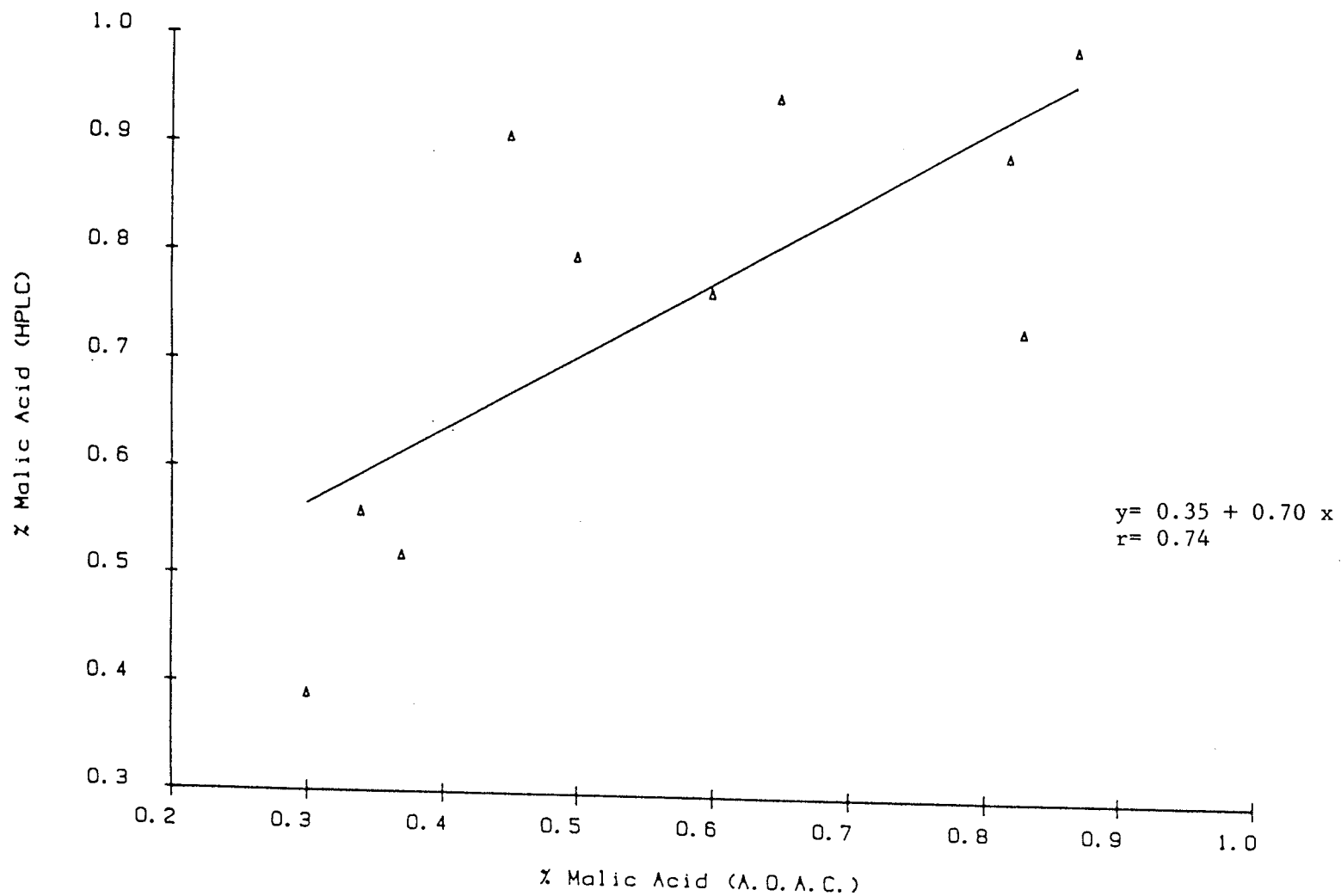


Figure 12. Comparison of total acidity analysis in apple juice by
Official and HPLC methods



apple juice (Poll, 1983a). The intensity and quality of the aroma in apple juice is very important in determining the overall quality of the product. In the first phase of sensory evaluation the panelists identified two descriptors for aroma (section 3.3.4), apple and fermented. The second phase determined aroma intensity using Quantitative Descriptive Analysis.

A summary of the analysis of variance for fermented aroma as described by panelists is presented in Appendix 14. The F values indicated that there were significant differences between panelists, cultivars and replications at the 5% level. There were no significant interactions (Appendix 14). This indicated that the panelists were scoring the juice samples similarly. The significant difference between panelists indicated that the panelists were not using the same portion of the QDA line. It may also be due to inadequate training. However, this is not surprising as aroma training usually takes from six months to one year (Durr, 1979). The replications were significant which indicated that the panelists as a group were scoring higher for Rep 1 (mean =16.18) compared to Rep 2 (12.62) (Appendix 15). Cultivar mean scores for fermented aroma are shown in Table 18. PF #51 was significantly different from the other cultivars indicating that it had the highest fermented aroma. In contrast, Collet had the least fermented aroma. The cultivars in the middle group ie. Kerr, Norland, Heyer #12, PF #50 and Goodland were not significantly different from each other but were significantly different from Westland, Breakey, Collet and PF #51.

The analysis of variance data for apple aroma are presented

Table 18. Cultivar mean score for fermented aroma in apple juice

Cultivar	Mean ¹
PF #51	25.83 a
PF #36	17.83 b
Kerr	16.11 bc
Norland	15.50 bcd
Heyer #12	14.78 bcd
PF #50	12.50 bcd
Goodland	11.61 bcd
Westland	10.44 cd
Breakey	10.05 cd
Collet	9.39 d

¹scores with the same letter are not significantly different ($p = .05$)

in Appendix 16. Again, significant differences were observed for panelists, cultivars and pan*cul interaction. There were no significant differences for replicates and pan*rep interaction. Cultivar mean scores for apple aroma are shown in Table 19. Collet was significantly different from Breakey , Goodland, Norland, Kerr, PF #36, and PF #51. In general those cultivars with low fermented aroma were scored high for apple aroma. For example, Collet had a low score for fermented aroma but a high score for apple aroma.

The characteristic apple like aroma is contributed by a complex mixture of esters, alcohols and aldehydes (Abbot et al. 1977 Poll 1983a). Panasuik et al. (1980), Flath et al. (1967); Guadgani et al. (1966) correlated aroma with volatile composition in McIntosh and Golden Delicious apples using gas chromatography. These GLC-Odor description investigations have reported particular components like ethyl 2-methyl butyrate, hexenal, trans-2-hexenal and unsaturated C-6 alcohols to be directly associated with apple-like aroma. Panasuik et al. (1980) reported that esters correlated highly with the "Cheesy aroma", which suggests that the fermented aroma might be due to the esters.

4.4.2. Flavor (by mouth) Evaluation Of Apple Juice

Flavor is a complex sensation in which all factors interact where volatile components contribute to aroma, the non-volatiles primarily give rise to taste sensation, hence the effect of one on the other must not be overlooked. As far as flavor by mouth is concerned, differences in juices are largely due to acids, sug-

Table 19. Cultivar mean score for apple aroma in apple juice

Cultivar	Mean ¹
Collet	21.67 a
PF #50	19.89 ab
Heyer #12	17.83 abc
Westland	16.89 abcd
Breakey	15.78 bcd
Goodland	15.33 bcd
Norland	12.89 cde
Kerr	11.83 de
PF #36	11.67 de
PF #51	8.55 e

¹scores with the same letter are not significantly different ($p = .05$)

ars, phenolics and fruity characteristics. It is known that acids contribute to acidity, sugars to sweetness, the phenolics to bitterness and astringency, but little is known about the effect of interaction of individual acids, phenolics or aroma components.

4.4.2.1. Apple Flavor

The F values (Appendix 17) indicated that cultivars and panelists were significantly different at the 5% level. However, the interactions were not significantly different. Replicates were not significantly different which demonstrates that the panelists were consistent from one session to the next. Panelists rated the apple flavor for Kerr, PF #51, Goodland, Collet, Norland, and PF #36 to have similar quality (Table 20), while the cultivars Goodland, Collet, Norland, PF #36, PF #50, Heyer #12 and Breakey had similar apple flavor quality. Westland was judged to have a distinctly different apple flavor.

One might expect both the apple flavor (by mouth) and apple aroma (nasal) to have similar scores. However, this was not the case as cultivar scores were higher for apple flavor (Table 20) than apple aroma (Table 19). This indicated that the flavor (by mouth) was identified from aroma (nasal) as totally different attributes. The lower scores for apple aroma (nasal) could also be due to the fermented aroma which might have masked the apple aroma.

4.4.2.2. Sweetness

The apple cultivars were distinctly different for sweetness quality (Table 21 and Appendix 18). Panelists rated sweetness

Table 20. Cultivar mean score for apple flavor in apple juice

Cultivar	Mean ¹
Kerr	31.94 a
PF #51	31.05 a
Goodland	29.11 ab
Collet	27.78 ab
Norland	26.83 ab
PF #36	25.72 ab
PF #50	24.00 b
Heyer #12	23.00 b
Breakey	22.56 b
Westland	10.56 c

¹ scores with same letter are not significantly different ($p = .05$)

Table 21. Cultivar mean score for sweetness in apple juice

Cultivar	Mean ¹
PF #51	39.83 a
Norland	30.33 b
PF #36	27.72 b
Collet	19.33 c
Breakey	16.94 cd
Goodland	13.39 de
Kerr	12.89 de
PF #50	12.00 de
Heyer #12	9.78 e
Westland	4.94 e

¹scores with the same letter are not significantly different ($p = .05$)

differently and their ratings changed from replicate to replicate. However there were no significant interactions. Of all the juice samples PF #51 was judged to produce the sweetest juice while juice from Westland was considered to be the least sweet. Juices produced from the Norland and PF #36 cultivars (next to PF #51) were given higher ratings than the next three groups of juice. These groupings were as follows: Collet and Breakey; Breakey, Goodland, Kerr and PF #50; Goodland, Kerr, PF #50 Heyer #12 and Westland.

Correlations were anticipated between perceived sweetness and sugar content determined by official methods (Figure 13) and HPLC analysis (Figure 14). The lack of correlation probably was due to the acidity level affecting the sensory response to sweetness. This was supported by a nonsignificant correlation between perceived sweetness and sugar content. Panelists were able to perceive the changes in sugar content. However the change in scores for sweetness did not directly correspond with an increase in sugar content (Appendix 19). This indicated that the sugar content by itself did not have an influence on the panelists perception of sweetness, ie. the cul*pan interaction was not significant (Appendix 18).

4.4.2.3. Sourness

Cultivar mean scores for sourness are presented in Table 22. Westland was rated as the cultivar producing the most sour juice while PF #51 produced the least sour juice. This rating was the reverse of that given for sweetness (section 4.4.2.2.). Juices

Figure 13. Correlation between perceived sweetness by sensory panel with sugar content by the Official method

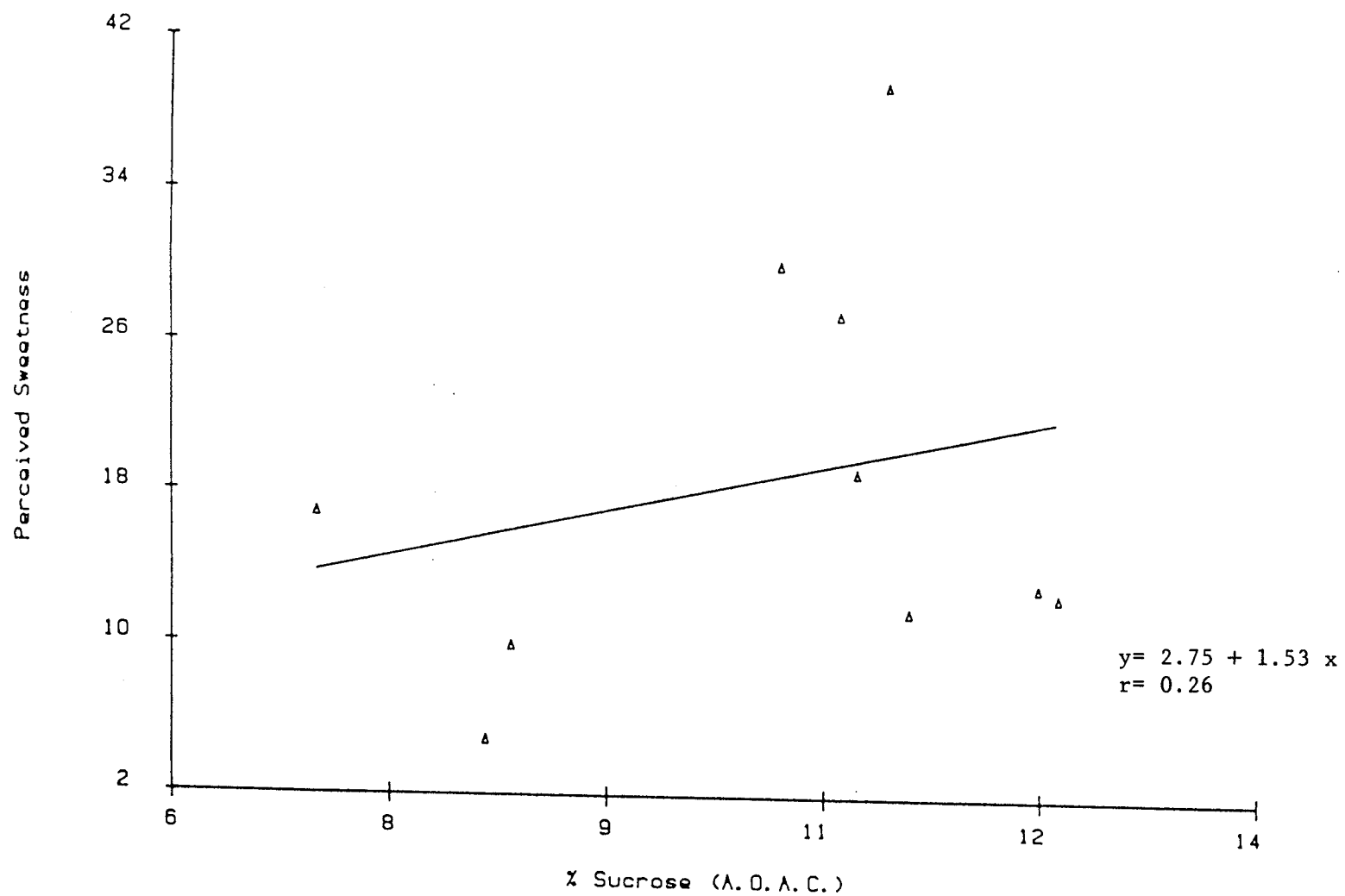


Figure 14. Correlation between perceived sweetness by sensory panel with sugar content by HPLC

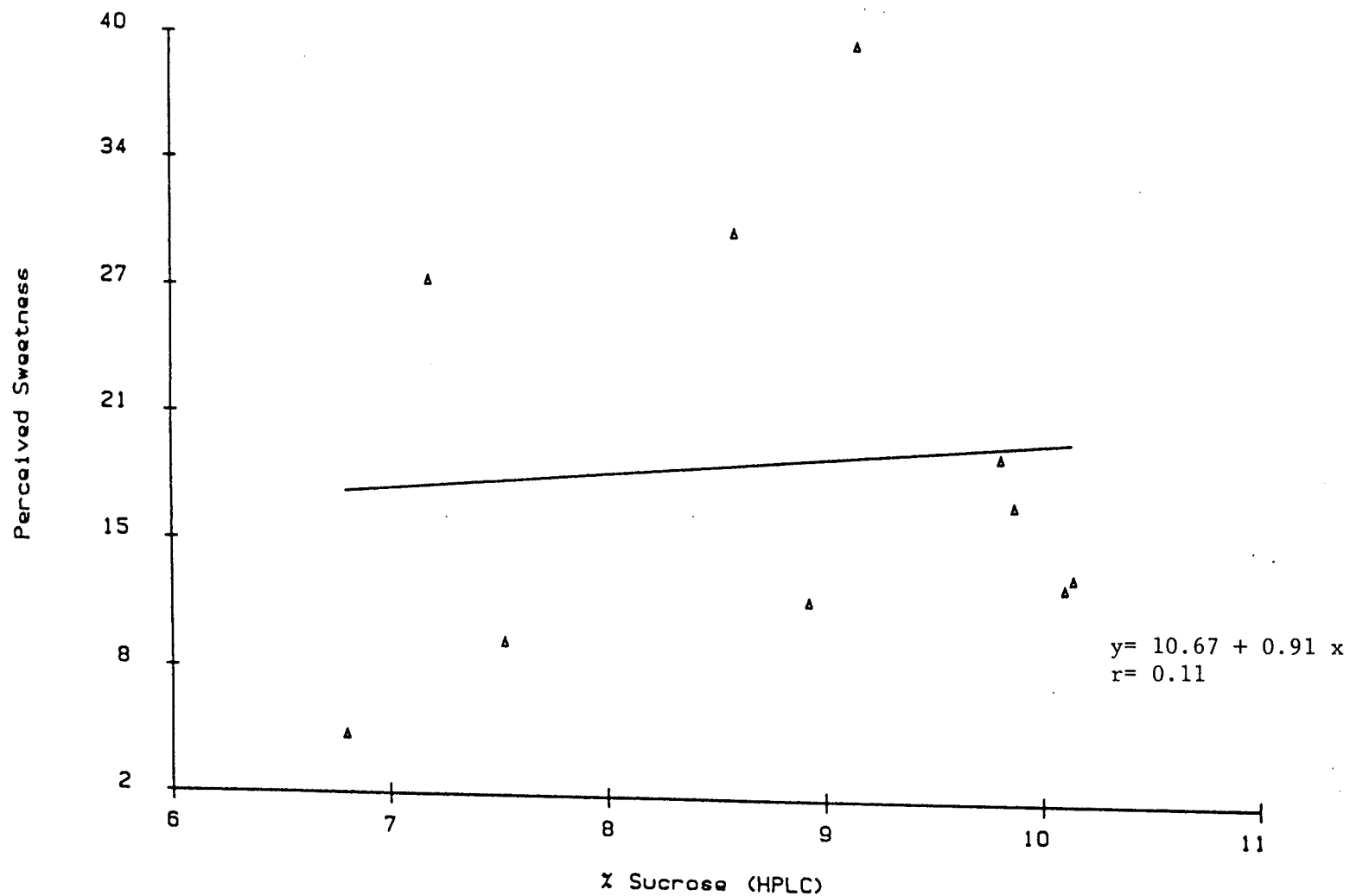


Table 22. Cultivar mean score for sourness in apple juice

Cultivar	Mean ¹
Westland	53.89 a
Kerr	46.39 b
Heyer #12	44.39 b
Goodland	44.22 b
PF #50	42.50 bc
Collet	38.83 c
Breakey	28.72 d
Norland	19.00 e
PF #36	16.39 e
PF #51	11.89 f

¹scores with the same letter are not significantly different ($p = .05$)

from Kerr, Heyer #12, Goodland and PF #50 were grouped together for sourness. These were more sour than the other cultivars but not as much as Westland juice. Other groupings in decreasing order of sourness were: PF # 50 and Collet; Breakey; Norland and PF #36. The ANOVA data (Appendix 20) indicated significant interactions between cultivar juices and panelists, and cultivar juices and replicates. Scores for sourness increased as the acid content increased (Appendix 21). A significant ($p=.01$) correlation was noticed between perceived sourness and acid content determined by official methods ($r=0.935$) (Figure 15) and HPLC ($r=.817$) (Figure 16). This indicated that the acid content had an influence on the taste (perceived sourness).

4.4.2.4. Astringency

The panelists were able to classify the ten cultivars into separate groups for astringency (Table 23 and Appendix 22). However they differed in their assessment of the degree of astringency (Appendix 22) and this produced a significant panelist*cultivar interaction. The juice from PF #51 was considered to be the least astringent followed by PF #36, Norland and Breakey. The juices from the rest of the cultivars were rated similarly by the panelists. A positive correlation ($r=.630$, significant at $p=.05$) was observed between perceived astringency and tannic acid determined by official methods (Figure 17). This indicated that the polyphenol content had an influence on the taste.

4.4.3. Descriptive Flavor Profile Of Apple Juice

Figure 15. Correlation between perceived sourness by sensory panel with acid content by Official method

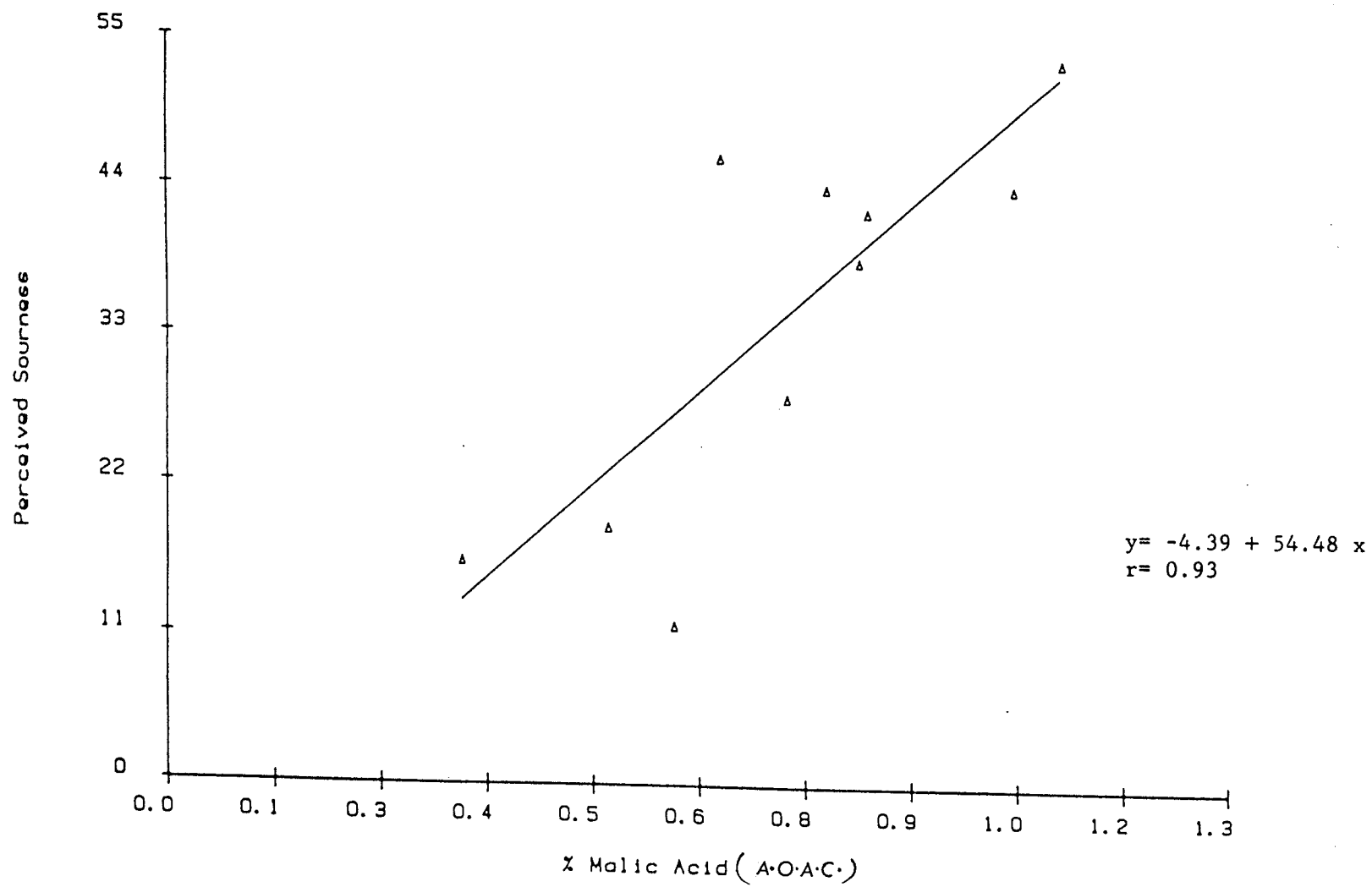


Figure 16. Correlation between perceived sourness by sensory panel with acid content by HPLC

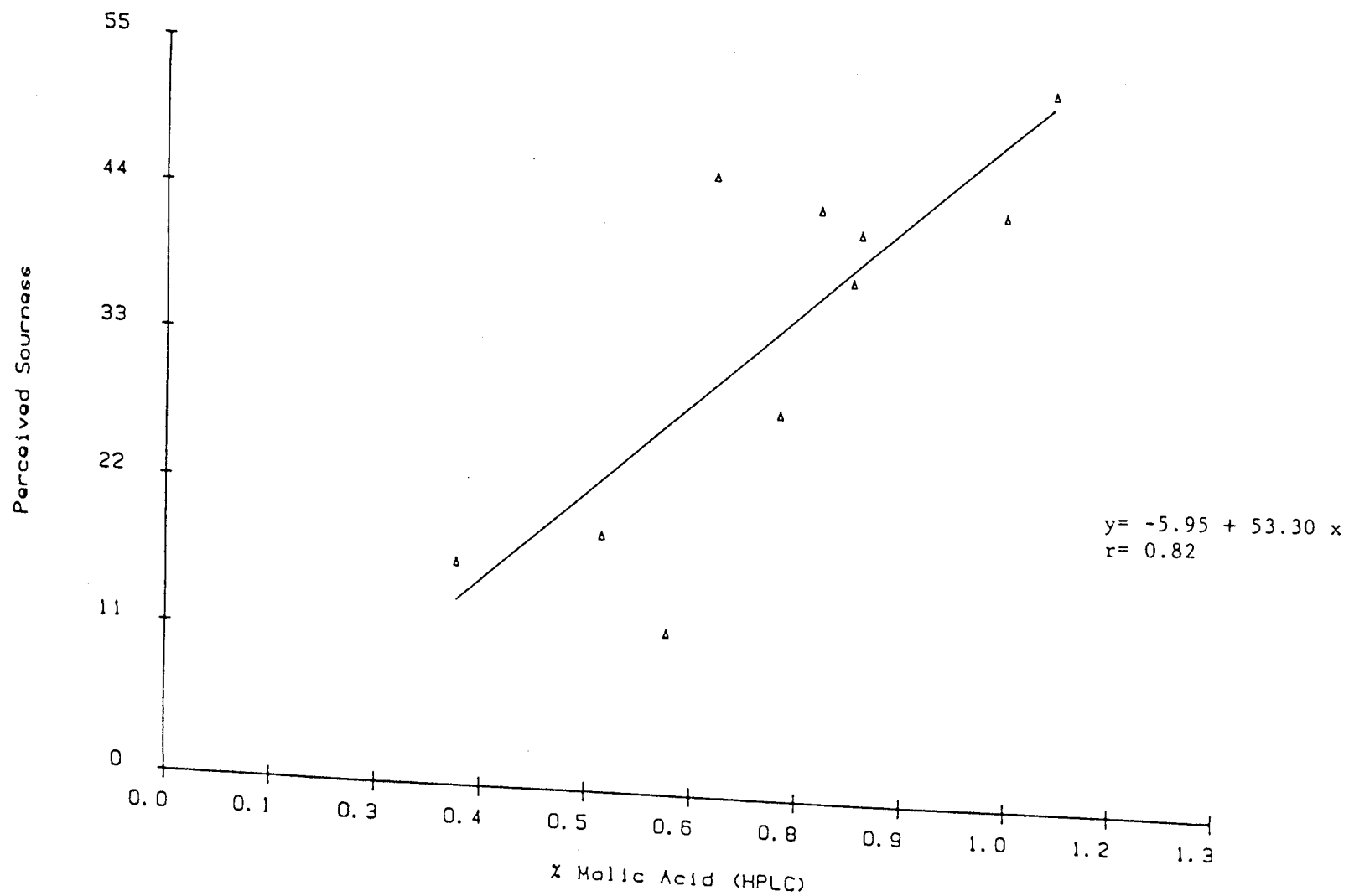
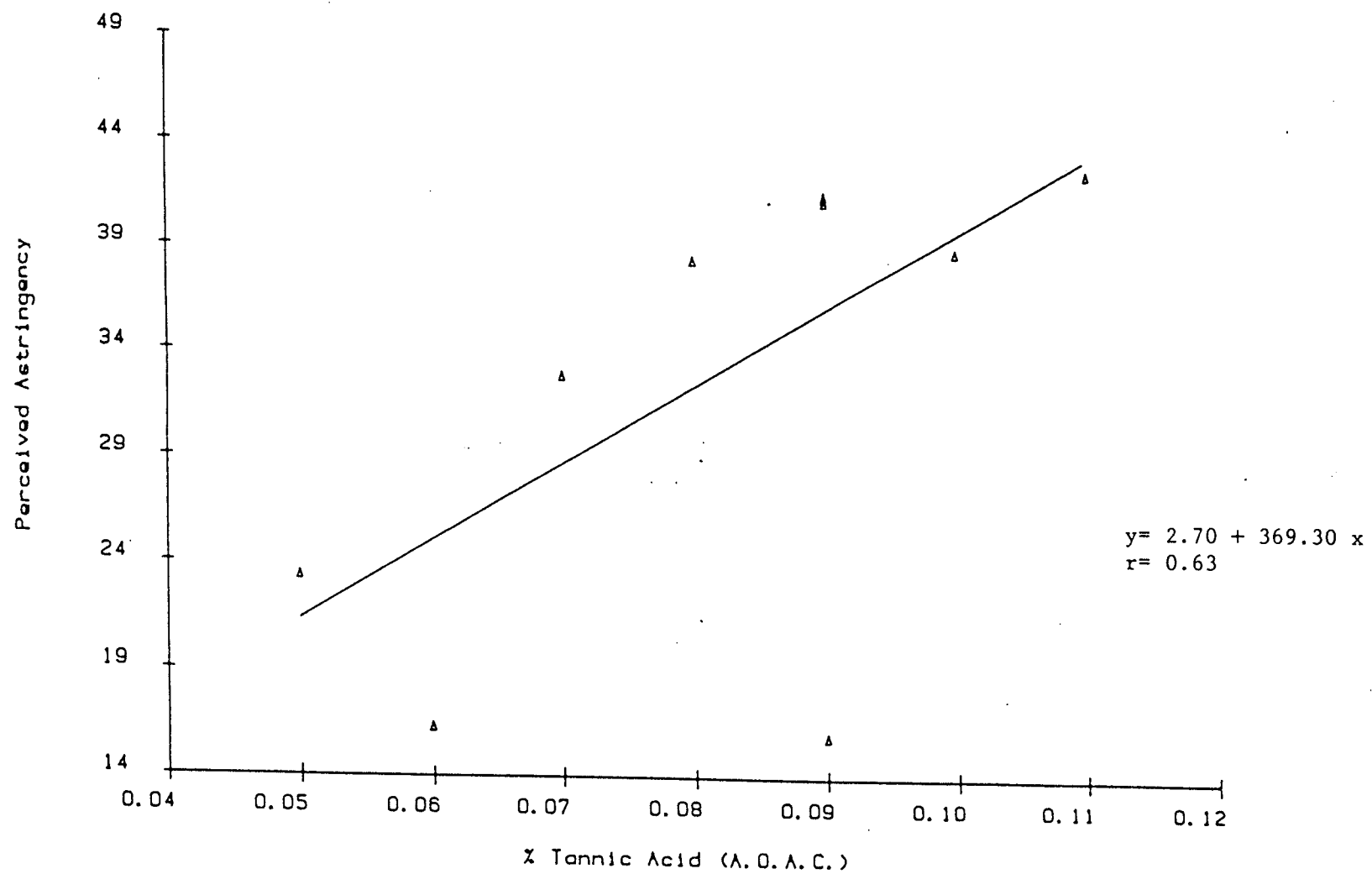


Table 23. Cultivar mean score for astringency of apple juice

Cultivar	Mean ¹
Goodland	42.83 a
Kerr	41.61 a
Heyer #12	41.50 a
Westland	41.33 a
PF #50	39.00 a
Collet	38.50 a
Breakey	32.94 b
Norland	23.39 c
PF #36	22.44 c
PF #51	16.33 d

¹scores with the same letter are not significantly different ($p = .05$)

Figure 17. Correlation between perceived astringency by sensory panel with tannin content by the Official method



A descriptive flavor profile of apple juice is illustrated in Figure 18. The center of the figure represents low intensity, with intensity of each attribute increasing with distance from the center. The mean values of each attribute are connected to yield a descriptive profile. In Figure 18 blends #1 and #4 (Appendix 2) are compared with a commercial apple juice (reference). The reference had the highest intensity for apple flavor and sweetness as compared to blend #1 and #4. However, with respect to apple flavor and sweetness blend #1 was not very different from blend #4 and the reference. Blend #4 had the highest intensity for sourness and astringency whereas the reference had the lowest intensity, with blend #1 intermediate to these. Blend #4 had the highest intensity for sourness and astringency because it consisted of a certain proportion of apple juice made from Kerr a crabapple. According to Moyer and Aitken (1980) crabapples (Kerr) are very astringent in taste. It was also observed that the reference had the highest intensity for sweetness, the reason being it had a sugar-acid ratio of 25.6 whereas the two blends #1 and #4 had a sugar-acid ratio of 17.0 (Table 24). According to Poll (1981) a sugar-acid ratio of 15 - 18 appears to give an ideal balance, with 18 - 23 being too sweet. Hence these results are in agreement with those reported by Poll (1981).

4.4.4. Effect of Sugar-Acid Ratio on Perceived Sweetness and Sourness

The sugar-acid ratios were determined from the measured sugar

Figure 18. Descriptive flavor profile of apple juice

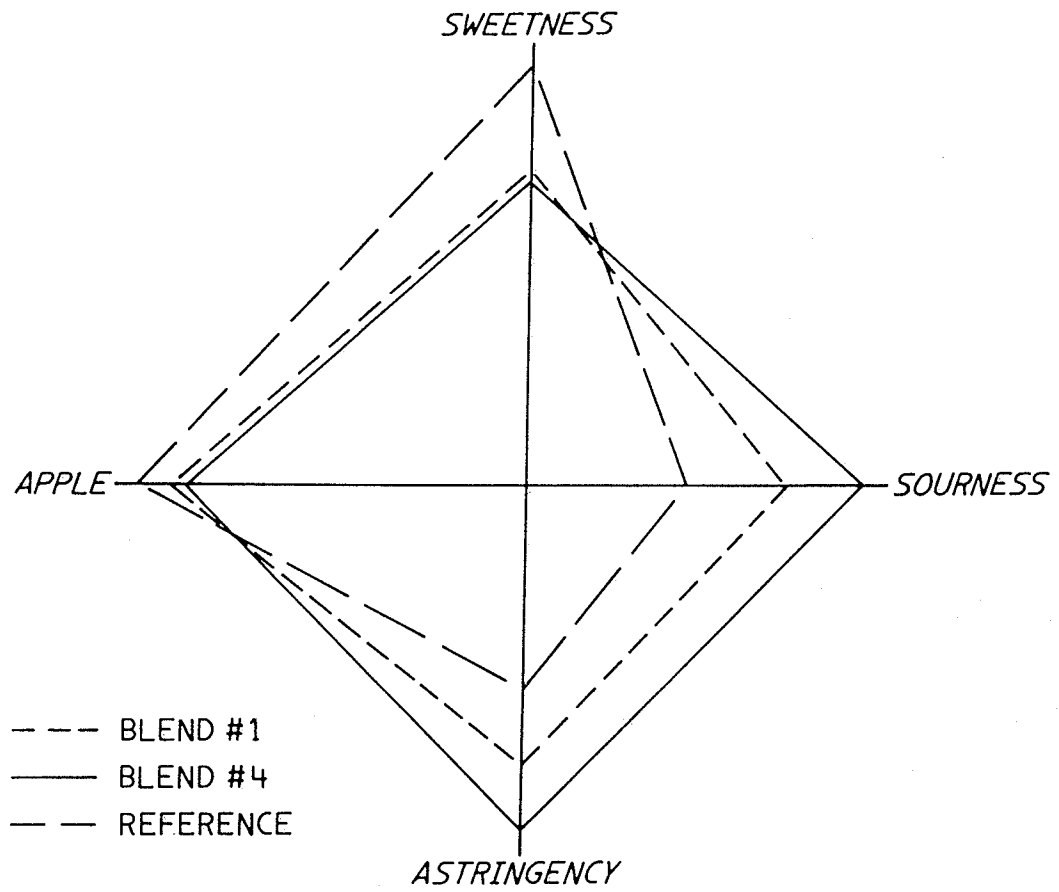


Table 24. Chemical and sensory analyses of blended and commercial apple juice

	Sugar Mean	Perceived Sweetness	Acid Mean	Perceived Sourness	Sugar-Acid Ratio
Blend #1	10.67	27.70	0.60	23.00	17.78
Blend #4	10.37	26.57	0.61	29.30	17.01
Reference	11.51	37.62	0.45	14.25	25.58

and acid contents (Section 3.1.2.). The sugar-acid ratios and the perceived sweetness and sourness scores are presented in Appendix 24. Panelists responded to the changes in the sugar-acid ratio. Thus sweetness scores increased as the sugar-acid ratio increased and the sourness scores increased as the sugar-acid ratio decreased, that is as the acidity of the juice increased. Perceived sweetness correlated positively ($r=.89$) with sugar-acid ratio (Figure 19). while sourness correlated negatively ($r=-.93$) with the sugar-acid ratio (Figure 20). It is evident that cultivars with high sugar-acid ratios were evaluated as sweet while cultivars with low values were judged as sour. Accordingly the juice from cultivar Kerr, Heyer #12, Goodland, PF #50 and Westland could be classified as being very sour, whereas juice from Norland, PF #36 and PF #51 as being very sweet and that from Breakey and Collet as having an ideal balance. These results are in agreement with those reported by Poll (1983).

Figure 19. Relationship of perceived sweetness against sugar-acid ratio

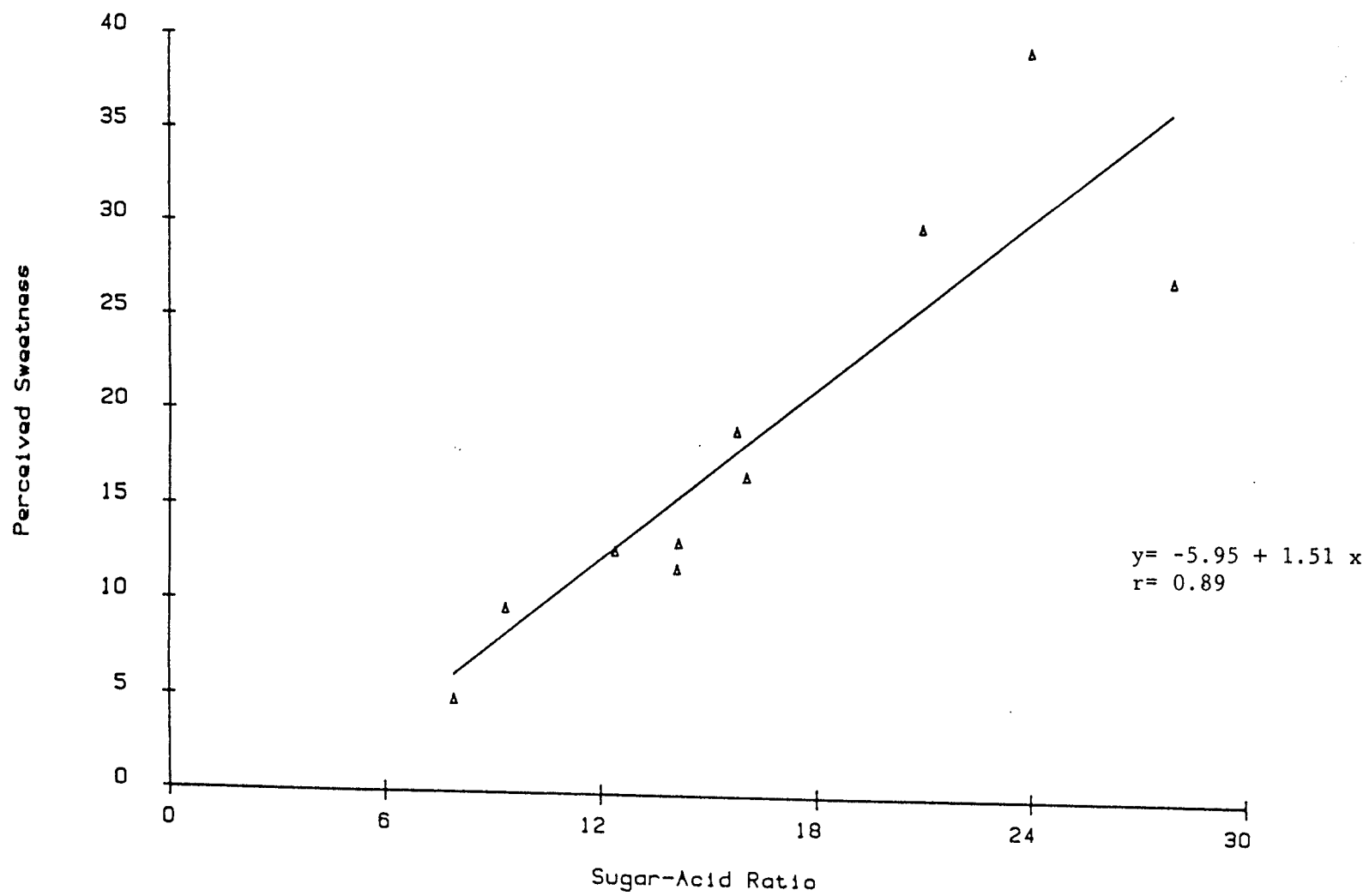
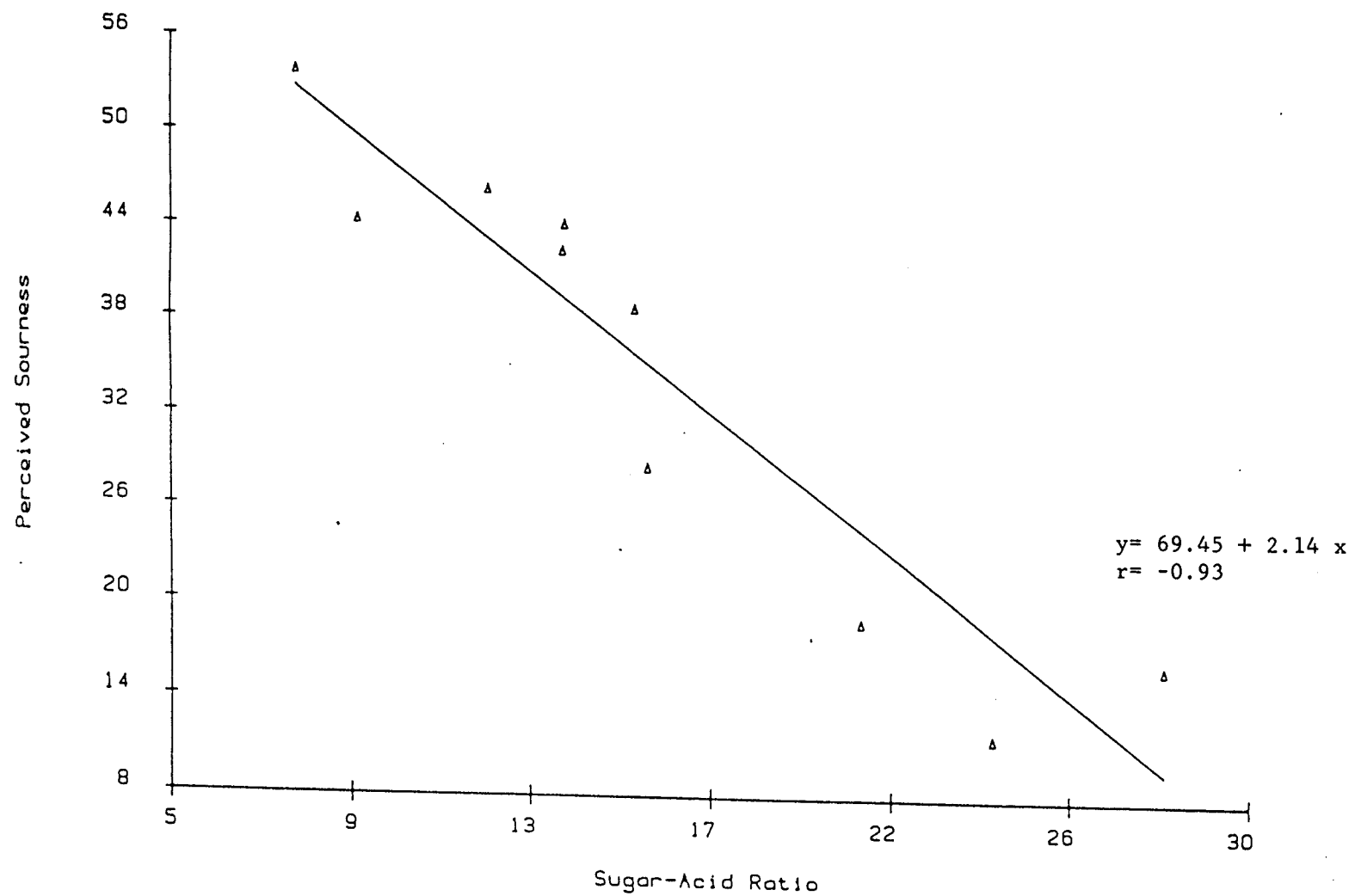


Figure 20. Relationship of perceived sourness against sugar-acid ratio



5. CONCLUSION

The present study was conducted on one crabapple and nine apple cultivars grown on the Canadian Prairies, to test their suitability for juice production. The criteria used to assess fruit qualities were:

1. Moisture content
2. Acid content
3. Sugar content
4. Polyphenol content

A pilot plant scale filtration unit was assembled and utilized for clarification, polishing and sterilization of the juice. The juice was analyzed chemically for pH, acid sugar and polyphenol content. Sugar and acid profiles on the juices was obtained by chromatographic (HPLC) analysis. The juice from each individual cultivar as well as a ten blends were evaluated organoleptically for aroma and flavor. Correlation of sensory with chemical and physical measurements were carried out for sugars and acids in the apple juice.

The two year data for moisture, acid, sugar and polyphenol content indicated considerable variation between and within cultivars from year to year. These cultivars could be classified as having average moisture content, medium to high acid content, average to below average sugar content and medium to high phenolic content.

The filtration studies indicated that the optimum enzyme (pectinase) concentration for clarification of apple juice was 0.15% (w/v). A constant turbidity value was obtained after the 4th filtration cycle. The test juice had a lower turbidity

value as compared to that of commercial apple juice. The yeast and mold count was nil on the final product. During filtration the polyphenol content decreased considerably due to removal of tannins along with suspended particles. Chromatographic analysis for sugars showed that fructose was the predominating sugar, with smaller amounts of glucose, sucrose, sorbitol and xylose. The major organic acids were malic and quinic, along with trace amounts of galacturonic and citric acid. However, quinic acid was not detected in the 1983 apple juice.

Organoleptic studies revealed that PF #51 and Collet had the highest scores for fermented and apple like aroma respectively. Sugar content by itself did not have an influence on the panelists perception of sweetness. Perceived sweetness increased with an increase in the sugar-acid ratio, on the other hand, perceived sourness increased with a decrease in the sugar-acid ratio. Only Breakey and Collet had the acceptable sugar-acid ratio required to make single cultivar juice. The other cultivars were less suitable due to a wider range of compositional differences. A proper blending procedure would permit the utilization of all cultivars for juice production. However, it should be remembered that all commercial apple juices are blended. The blended juices compared very well with the commercial apple juice.

6. RECOMMENDATIONS

In this study the following recommendations are made for future study:

To overcome the yeast and mold problem, the entire system needs to be redesigned. This could be achieved by replacing the PVC piping with stainless pipes. The shelf life of the apple juice could be further improved by eliminating all the filters and inserting an ultrafiltration membrane.

Commercially apple juice is blended by mixing juice from two or more cultivars. Since juice from Manitoba grown apples have never been evaluated, a proper blending procedure would permit the utilization of all these cultivars. This can be achieved by increasing the sugar-acid ratio from 17 to 25. These blends could then be compared with a commercial apple juice. Each apple producing area has its own favourite apple juice. Hence a preference test could be carried out to the consumer group to evaluate the acceptability of apple juice as well as carbonated apple juice from Manitoba grown apples.

7. BIBLIOGRAPHY

- A.O.A.C. 1975. Official Methods of Analysis. 12th Ed. Association of Official Analytical Chemists. Washington, D.C.
- Alston, F.H. 1979. Breeding High Quality High Yielding Apples. Chapter 11.3. Quality in Stored and Processed Vegetables and Fruits. Goodenough, P.W. and Atkin, R.K. (Eds). Academic Press. pp 93-102.
- American Public Health Association and American Water Works Association. 1975. Standard Methods For The Examination of Water and Waste Water. A.P.H.A. 1015, 18th St. NW. Washington, D.C.
- Anonymous. 1974. Commercial Storage of Fruits and Vegetables. 1532. Agriculture Canada. 930 Carling Avenue. Ottawa, Ontario.
- Anonymous. 1981. Departmental Consolidation of the Food & Drugs Act and of the Food and Drugs Regulations. Department of National Health & Welfare. Ministry of Supply and Services, Canada. p 55.
- Anonymous. 1982. Clarifying Apple Juice with Pectinol Pectic Enzymes. Genencor, Inc. Baron Steuben Place, Corning, New York.
- Arengo-Jones, R.W. 1940. The Preparation and Preservation of Apple Juice. Fruit Prod. J. 19:327-330.
- Baker, G.A. and Amerine, M.A. 1953. Organoleptic Ratings of Wines Estimated From Analytical Data. Food Res. 18:381-389.
- Bauman, J.W. 1981. Application of Enzymes in Fruit Juice Technology. Chapter 7. Enzymes and Food Processing. Brich, G.G., Blakebrough, N. and Parker, K.J. (Eds). Applied Science Ltd. London. pp 129-147.
- Biles, B. and Emerson, T.R. 1968. Examination of Fibers in Beer. Nature. 291:293.
- Black, A.P. and Hannah, S.A. 1965. Measurement of Low Turbidities. J. Amer. Water Works Assoc. July 1965:901-915.
- Bradley, B.F. and Brown, B.I. 1969. The Influence of Maturity and Storage of Granny Smith Apples at Ambient Temperatures on the Quality of Canned Apple Juice. Food Tech. Aust. May 1969:212-217.

- Bright, R.A. and Potter, N. 1979. Acceptability and Properties of Carbonated Apple Juice. Food Prod. Dev. April 1979:34-37.
- Carpenter, D.C., Pederson, C.S. and Walsh, W.F. 1932. Sterilization of Fruit Juices by Filtration. Ind. Eng. Chem. 24:1218-1223.
- Carpenter, D.C. 1933. Carbonated Apple Juice. Fruit Product J. 13:37.
- Charley, V.L.S. 1932. Investigations on Fruit Products. Bristol Univ. Agr. and Hort. Res. Sta. Ann. Rpt. 214-231.
- Clauge, J.H. and Fellers, C.R. 1936. Apple Cider and Cider Products. Mass. Agr. Expt. Sta. Bul. 336.
- Compendium of Methods For The Microbiological Examination of Foods. 1984. Section 17.52. Acidified Method. Speck, M.L. (Ed). American Public Health Association. Washington, D.C.
- Coppola, E.D. 1984. Use of HPLC to Monitor Juice Authenticity. Food Technol. April 1984:88-91.
- Damon, C.E. and Pettitt, C. 1980. High Performance Liquid Chromatographic Determination of Fructose, Glucose, and Sucrose in Molasses. J. Assoc. Off. Anal. Chem. 63:476-480.
- Dimick, P.S. and Hoskin, J.C. 1981. Review of Apple Flavor-State of The Art. CRC Critical Reviews in Food Sci. and Nut. CRC Press Inc. Cleveland, Ohio, U.S.A. 18:387-408.
- Dryden, E.C. and Hill, C.H. 1957. Consumer Preference Studies on Applesauce. Food Technol. 11:589.
- Durr, P. 1979. Development of an Odour Profile to describe Apple Juice Essences. Lebensm-Wiss. u.-Technol. 12:23-26.
- Eskin, N.A.M., Henderson, H.M. and Townsend, R.J. 1971. Enzymes in the Food Industry. Chapter 4. Biochemistry of Foods. Academic Press. London. pp 109-148.
- Esselen, W.B. 1945. A Study of Methods of Clarification and Blends of Massachusetts Apples for Apple Juice. Fruit Prod. J. February 1945:165-145.
- Evans, R.H., Van Soestbergen. A.W. and Ristow. K.A. 1983. Evaluation of Apple Juice Authenticity by Organic Acid Analysis. J. Assoc. Off. Anal. Chem. 66:1517-1520.

- Fiore, J.V. and Babineau, R.A. 1979. Filtration. Food Technol. April 1979:67-72.
- Flath, R.A., Black, D.R., Guadagni, D.G., McFadden, W.H., and Schult, T.H. 1967. Identification and Organoleptic Evaluation of Compounds in Delicious Apple Essence. J. Agric. Food Chem. 15:29.
- Grove, O. 1930. Cider Making Trials With Nova Scotian Apples. Bristol Univ. Agr. and Hort. Res. Sta. Ann. Report. 192-194.
- Guadagni, D.G., Okano, S., Buttery, R.G. and Burr, H.K. 1966. Correlation of Sensory and Gas-Liquid Chromatographic Measurements of Apple Volatiles. Food Technol. April 1966:166-169.
- Hach, C.C. 1976. Developments in Water/Wastewater Analysis Chemistry, Methods and Instrumentation. A Publication of Hach Chemical Co., Ames, Iowa.
- Hathaway, D.E. and Seakins, J.W.T. 1958. The Influence of Tannins on the Degradation of Pectin by Pectinase Enzymes. J. Biochem. 70:158-163.
- Heatherbell, D.A. 1976. Haze and Sediment Formation From Starch Degradation Products in Apple Wine and Clarified Apple Juice. Confructa. 21:36-42.
- Heimenz, P.C. 1977. Principles of Colloid and Surface Chemistry. Marcel Dekker, Inc. New York. pp 195.
- Hulme, A.C. 1958. Some Aspects of the Biochemistry of Apple and Pear Fruits. Advan. Food Res. 8:297-413.
- Hurst, W.J., Martin, R.A. and Zoumas, B.L. 1979. Application of HPLC to Characterization of Individual Carbohydrates in Foods. J. Food Sci. 44:892-895.
- John, T.N. 1982. Sterile Filtration-Some Myths and Fables. Aust. Grapegrower and Winemaker. August 1982:16-18.
- Johnson, G., Donnelly, B.J. and Johnson, D.K. 1968. The Chemical Nature and Precursors of Clarified Apple Juice Sediment. J. Food Sci. 33:254-257.
- Joslyn, M.A. 1970. Moisture Content and Total Solids. Chapter 4. Methods in Food Analysis. Joslyn, M.A. (Ed). Academic Press, London. pp 73-99.

- Kilara, A. 1982. Enzymes and Their Uses in the Processed Apple Industry: A Review. *Process Biochem.* July/August 1982:35-41.
- Kime, R. 1983. The Discovery of a New Use for Honey. *American Bee J.* 123(8):586.
- Kochan, A. 1968. Evaluation of Optimal Quality of Apple Juice. *Flussiges Obst.* 35:514-518.
- Krishnaprakash, M.S., Aravindaprasad, B., Krishnaprasad, C.A., Narasimham, P., Ananthakrishna, S.M., Dhanraj, S. and Govindarajan, V.S. 1983. Effect of Apple Position on the Tree on Maturity and Quality. *J. Hort. Sci.* 58:31-36.
- Larmond, E. 1977. Laboratory Methods for Sensory Evaluation of Food. Publication 1637. Research Branch, Canada Department of Agriculture. p 48-49.
- La Belle, R.L., Shallenberger, R.S., Way, R.D., Mattick, L.R. and Moyer, J.C. 1960. The Relationship of Apple Maturity to Apple sauce Quality. *Food Technol.* 14:463.
- La Belle, R.L. 1981. Apple Quality Characteristics as Related to Various Processed Products. Chapter 6. Quality of Selected Fruits and Vegetables of North America. Teranishi, R. and Barrera-Benitez, H. (Eds). ACS Symposium Series 170. American Chemical Society, Washington, D.C. pp 61-75.
- Lopez, A., Fellers, P.J., Wood, C.B. and Johnson, J.M. 1958. Composition of Ten Processing and Table Varieties of Virginia Apples. *J. Food Res.* 23:492-504.
- Marshall, C.R. and Walkley, V.T. 1951. Some Aspects of Microbiology Applicable to Commercial Apple Juice Production. II. Microbiology of Processing. *Food Res.* 16:515-521.
- McLellan, M.R., Kime, R.W. and Lind, L.R. 1985. Apple Juice Clarification with the Use of Honey and Pectinase. *J. Food Sci.* 50:206-208.
- Mecredy, J.M., Sonnemann, J.C. and Lehmann, S.J. 1974. Sensory Profiling of Beer by a Modified QDA Method. *Food Technol.* Nov. 1974: 36-41.
- Mian, M.M. and Bhatti, M.B. 1969. Various Factors Affecting the Clarification of Apple Juice. *Agric. Pakistan.* 20:415-421.
- Minsker, F.C. 1962. Determination of Sorbitol in Vinegar. *J. Assoc. Off. Agric. Chem.* 45:562-564.

- Moskowitz, H.R. and Van Sydow, E.J. 1975. Computer Derived Perceptual Maps of Flavors. J. Food Sci. 40:788-792.
- Moyer, J.C. and Aitken, H.C. 1980. Apple Juice. Chapter 6. In Fruit and Vegetable Processing Technology. Neilson, P.E. and Tressler, D.K. (Eds). Third Ed. Avi Publishing Co., Inc. Westport, Connecticut. pp 212-267.
- Nerad, F. 1981. Modern Filtration Techniques. Aust. Grapegrower and Winemaker. September 1982:9-12.
- Neubert, A.M. 1943. Effect of Filtration on Appearance, Viscosity, and Alcohol-Insoluble Fraction of Apple Juice. Food Res. 8:477-488.
- Neubert, A.M. and Veldhuis, M.K. 1944. Clouding and Sedimentation in Clarified Apple Juice. Food Products J. and Am. Food Manufacturer. 324-337.
- Nursten, H.E. and Wolfe, M.L. 1972. An Examination of the Volatile Compounds Present in Cooked Bramley's Seedling Apples and the Changes they Undergo on Processing. J. Sci. Fd. Agric. 23:803-822.
- Panasiuk, O., Talley, F.B. and Sapers, G.M. 1980. Correlation Between Aroma and Volatile Composition of McIntosh Apples. J. Food Sci. 45:989-991.
- Pederson, C.S. and Beattie, H.G. 1943. Buffering Effect of Fruit Juices. Food Res. 8:405-408.
- Peleg, Y. and Brown, R.C. 1976. Method for Evaluating the Filterability of Wine and Similar Fluids. J. Food Sci. 41:805-808.
- Poll, L. 1981. Evaluation of 18 Apple Varieties for Their Suitability for Juice Production. J. Sci. Food Agric. 32:1081-1090.
- Poll, L. 1983 a. The Influence of Apple Variety on Sensory Quality of Heated Apple Juice. Lebensm-Wiss. u.-Technol. 16:119-121.
- Poll, L. 1983 b. Influence of Storage Temperature on Sensory Evaluation and Composition of Volatiles of McIntosh Apple Juice. Lebensm-Wiss. u.-Technol. 16:220-223.
- Rankine, B.C. 1982. Filtration- State of the Art '82. Aust. Grapegrower and Winemaker. August 1982:12-14.

- Reeves, G.W. 1983. Wine Filtration in the Bottling Cellar. Food Technol. Aust. 36:28-33.
- Reyes, F.G.R., Wrolstad, R.E. and Cornwell, C.J. 1982. Comparison of Enzymic, Gas-Liquid Chromatographic, and High Performance Liquid Chromatographic Methods for Determining Sugars and Organic Acids in Strawberries at Three Stages of Maturity. J. Assoc. Off. Anal. Chem. 65:126-131.
- Richmond, L.M., Brando, S.C.C., Gray, J.I., Markakis, P. and Stine, C.M. 1981. Analysis of Simple Sugars and Sorbitol in Fruit by High Performance Liquid Chromatography. J. Agric. Food Chem. 29:4-7.
- Roland, J.O. and Beuchat, L.R. 1984. Biomass and Patulin Production by *Byssoschlamys nivea* in Apple Juice as Affected by, Sorbate, Benzoate, SO₂, and Temperature. J. Food Sci. 49:402-406.
- Ryan, J.J. 1972. Chemical Composition of Canadian Apple Juice. J. Assoc. Off. Anal. Chem. 55:1104-1108.
- Sapers, G.M., Abbott, J., Massie, D., Watada, A. and Finney Jr., E.E. 1977. Volatile Composition of McIntosh Apple Juice as a Function of Maturity and Ripeness Indices. J. Food Sci. 42:44-47.
- Schelorn, Von M. 1953. Control of Microorganisms Causing Spoilage in Fruit and Vegetable Products. Advances in Food Research. 3:431-472.
- Scott, W.T. and Bullerman, L.B. 1975. Patulin: A Mycotoxin of Potential Concern in Foods. J. Milk Food Tech. 38:695.
- Sharma, D.D. 1984. Chemical, Processing and Sensory Studies for the Production of Apple Juice From Ten Hardy Apple Cultivars Grown on the Canadian Prairies. M.Sc. Thesis. University of Manitoba, Winnipeg, Manitoba, Canada.
- Shaw, P.E. and Wilson, C.W. 1982. Separation of Sorbitol and Mannose from Fructose, Glucose and Sucrose on Reversed-Phase and Amine-Modified HPLC Columns. J. Chromatogr. Sci. 20:209-212.
- Simms, R.J. 1976. Turbidity Measurement in the Filtration of Beer. Brygmesteren. 33:243-256.
- Smock, R.M. and Neubert, A.M. 1950. Apple Juice, Sirup and Concentrate. Chapter 12. In Apples and Apple Products. Interscience Publisher Inc. New York. pp 313-376.

- Smolensky, D.C. and Vandercook, C.E. 1980. Detection of Grape Juice in Apple Juice. *J. Food Sci.* 45:1773-1780.
- Stone, H.S., Sidel, J.L. and Bloomquist, J. 1980. Quantitative Descriptive Analysis. *Cereal Foods World.* 25:642-644.
- Voho, K. and Varo, P. 1975. Chemical and Organoleptic Evaluation of some Finnish Apple Varieties. *J. Sci. Agric. Soc. Finl.* 47:445-453.
- Wale, R. 1982. Wine and Beverage Filtration by the Enclosed Cartridge System. *Aust. Grapegrower and Winemaker.* August 1982:22-23.
- Watada, A.E., Massie, D.R. and Abbott, J.A. 1985. Relationship Between Sensory Evaluations and Nondestructive Optical Measurements of Apple Quality. *J. Food Quality.* 7:219-226.
- Whistler, R.L. 1953. Starch Retrogradation. *Starch and its Derivatives.* Vol.1. Chapman and Hall, London. pp 213-228.
- Whiting, G.C. 1970. Sugars. Chapter 1. The Biochemistry of Fruits and their Products. Vol.1. Hulme, A.C. (Ed). Academic Press, London. pp 1-31.
- Wilson, A.M., Work, T.M., Bushway, A.A. and Bushway, R.J. 1981. HPLC Determination of Fructose, Glucose, and Sucrose in Potatoes. *J. Food Sci.* 46:300-301.
- Wilson, E.L., Hogg, M.G. and Burns, D.J. 1984. Sensory Evaluation of Clarified Kiwifruit Juices. *J. Food Quality.* 7:43-57.
- Williams, A.A. 1975. The Development of a Vocabulary and Profile Assessment Method for Evaluating the Flavor Contribution of Cider and Perry Aroma Constituents. *J. Sci. Fd Agric.* 26:567-582.
- Zyren, J. and Elkins, E.R. 1985. Interlaboratory Variability of Methods used for Detection of Economic Adulteration in Apple Juice. *J. Assoc. Off. Anal. Chem.* 68:672-676.

Appendices

Appendix 1.

Procedure utilized for blending of apple juice

Sugar-Acid Ratio			%
Norland	21	1.2	23.00
	17		
Collet	15.8	4.0	77.00
		5.2	100.00
		---	-----

Blending was based on a sugar-acid ratio of 17. Hence in the above example 1.2 parts of Norland (S/A = 21) is mixed with 4 parts of Collet (S/A = 15.8).

$$\begin{array}{r} 100 \times 1.2 = 23\% \\ \hline 5.2 \end{array}$$

$$\begin{array}{r} 100 \times 4.0 = 77\% \\ \hline 5.2 \end{array}$$

Appendix 2.

Prepared blends of apple juice

Blend	Cultivar	Proportion	
1	Collet	23.00	
	Norland	77.00	
2	Kerr	60.00	
	PF #51	40.00	
3	Collet	30.00	
	Kerr	70.00	
4	Goodland	59.00	
	Norland	41.00	50 ml
	Breakey	83.00	
	Kerr	17.00	50 ml
			100 ml
5	PF #36	30.00	
	Kerr	70.00	
6	PF #36	79.00	
	PF #50	21.00	
7	PF #36	41.00	
	Heyer #12	59.00	50 ml
	PF #50	71.00	
	PF #51	29.00	50 ml
			100 ml
8	Collet	70.00	
	Goodland	30.00	50 ml
	Norland	70.00	
	Westland	30.00	50 ml
			100 ml

Appendix 3.

Concentration of taste stimuli used in orientation panels			
% Fructose	% Malic acid	% Tannic acid	Preparation of Reference
0.2	0.02	0.002	w/v in tap distilled water
0.4	0.04	0.004	w/v in tap distilled water
0.6	0.06	0.006	w/v in tap distilled water
0.8	0.08	0.008	w/v in tap distilled water
1.0	0.10	0.010	w/v in tap distilled water

Appendix 4.

¹Questionnaire For ranking

Name_____

Date_____

Rank these samples for sweetness. The sweetest sample is ranked first, the second most sweetest sample is ranked second, the least is ranked last. Place the code numbers on appropriate lines.

Taste the samples in the following order. Rinse with water between each sample.

Code _____

Comments:

¹similar questionnaire was used for ranking sourness and astringency

Appendix 5.

Description Of apple juice

Name_____

Date_____

Taste each apple juice sample in the given order, and describe
aroma and flavor.

Code_____

Aroma

Flavor (by mouth)

Comments:

Appendix 6.

Sensory attributes selected by panel for evaluation Of apple juice

Characteristic	Attributes
Aroma	Apple Fermented Alcoholic
Flavor (by mouth)	Apple Sweetness Sourness Astringency

Appendix 7.

Reference samples used during aroma and flavor evaluation

Characteristic	Attribute	Reference
Aroma	Apple	Scotian Gold apple juice PF #51
	Fermented	
Flavor	Apple	Scotian Gold apple juice
	Sweetness	Scotian Gold apple juice
	Sourness	Scotian Gold apple juice
	Astringent	Scotian Gold apple juice

¹Scotian Gold apple juice²1984 juice from PF #51

Appendix 8.

The sequence Of Sample presentation for aroma evaluation
in apple juice

Date	Cultivar
26- 03-85	PF #36 Heyer #12 Goodland
28-03-85	PF #51 Collet Kerr
01-04-85	Westland Norland PF #50
03-04-85	Breakey

Appendix 9.

The sequence of sample presentation for flavor evaluation (by mouth)
in apple juice

Date	Cultivar
29-04-85	PF #50 Heyer #12
30-04-85	PF #36 Goodland
01-05-85	Kerr Breaker
02-05-85	PF #51 Westland
03-05-85	Collet Norland

Appendix 10

Sugars in apple juice (1983) as determined by HPLC

Cultivar	Sucrose		Glucose		Fructose		Sorbitol		Xylose		Total Sugar
	%	Std. Dev.	%	Std. Dev.	%	Std. Dev.	%	Std. Dev.	%	Std. Dev.	%
Kerr	0.77	0.03	2.82	0.06	4.70	0.14	0.40	0.02	¹ ND	ND	8.69
Breakey	0.95	0.05	1.55	0.04	6.86	0.22	0.51	0.01	0.12	0.01	9.99
Collet	0.41	0.03	1.57	0.06	5.25	0.21	0.31	0.01	0.13	0.00	7.67
Goodland	0.34	0.01	1.71	0.07	4.77	0.14	0.31	0.01	0.06	0.01	7.19
Heyer12	0.63	0.03	1.87	0.08	5.13	0.09	0.30	0.00	0.05	0.00	7.98
Norland	Trace		1.28	0.12	4.36	0.36	0.34	0.03	0.09	0.05	6.07
PF #36	0.68	0.00	2.10	0.08	5.47	0.21	0.32	0.01	0.11	0.00	8.68
PF #50	0.23	0.06	1.31	0.01	4.03	0.05	0.25	0.00	0.11	0.00	5.93
PF #51	0.56	0.02	2.05	0.08	3.52	0.13	0.29	0.08	ND	ND	6.42
Westland	ND	ND	1.21	0.08	4.29	0.13	0.29	0.08	ND	ND	5.87

¹ND Not Detected

Appendix 11

Sugars in apple juice(1984) as determined by HPLC

Cultivar	Sucrose %	Std. Dev.	Glucose %	Std. Dev.	Fructose %	Std. Dev.	Sorbitol %	Std. Dev.	Xylose %	Std. Dev.	Total Sugar %
Kerr	1.26	0.09	2.86	0.17	5.58	0.26	0.40	0.04	0.01	0.00	10.11
Breakey	1.21	0.01	1.60	0.01	6.48	0.30	0.52	0.00	0.07	0.01	9.88
Collet	0.60	0.00	1.32	0.01	7.40	0.07	0.39	0.00	0.11	0.01	9.82
Goodland	1.43	0.06	1.50	0.02	6.83	0.14	0.39	0.01	ND ²	ND	10.15
Heyer12	0.09	0.00	1.39	0.07	5.66	0.30	0.30	0.02	0.09	0.00	7.53
Norland	1.03	0.60	1.28	0.06	5.78	0.28	0.41	0.01	0.01	0.00	8.60
PF #36	0.71	0.01	1.49	0.01	4.57	0.05	0.35	0.00	0.07	0.00	7.19
PF #50	0.84	0.02	1.50	0.00	6.30	0.03	0.26	0.00	0.03	0.00	8.93
PF #51	1.61	0.02	2.11	0.06	5.08	0.05	0.35	0.00	0.02	0.00	9.17
Westland	0.21	0.01	1.60	0.09	4.83	0.05	0.14	0.00	0.02	0.00	6.80
S-Gold ¹	0.67	0.00	1.96	0.00	6.94	0.01	0.36	0.00	0.03	0.00	9.95
Blend#1	0.99	0.02	1.33	0.02	6.29	0.12	0.41	0.01	0.10	0.00	9.12
Blend#4	1.10	0.01	1.50	0.01	5.90	0.06	0.38	0.00	0.03	0.00	8.91

¹Scotian Gold

²ND Not Detected

Appendix 12

Organic acids in apple juice(1983) as determined
by HPLC

Cultivar	Citric %	Std. Dev.	Galacturonic %	Std. Dev.	Malic %	Std. Dev.	Total Acid %
Kerr	0.02	0.00	0.13	0.00	1.13	0.06	1.28
Breakey	0.03	0.01	0.08	0.03	1.06	0.11	1.17
Collet	0.01	0.00	0.14	0.02	0.76	0.03	0.91
Goodland	0.01	0.00	0.14	0.00	0.74	0.04	0.89
Heyer #12	0.06	0.00	0.10	0.00	0.96	0.05	1.12
Norland	0.03	0.01	0.09	0.03	0.58	0.02	0.72
PF #36	0.06	0.00	0.10	0.00	0.98	0.00	1.14
PF #50	0.05	0.00	0.06	0.00	1.04	0.03	1.15
PF #51	0.01	0.00	0.05	0.00	0.43	0.02	0.49
Westland	0.02	0.00	0.04	0.00	0.38	0.00	0.44

Appendix 13

Organic acids present in apple juice (1984) as determined
by HPLC

Cultivar	Citric %	Std. Dev.	Galacturonic %	Std. Dev.	Malic %	Std. Dev.	Quinic %	Std. Dev.	Total Acid %
Kerr	0.03	0.00	0.10	0.00	0.68	0.00	0.47	0.01	1.28
Breakey	0.04	0.00	0.08	0.01	0.76	0.11	0.51	0.07	1.39
Collet	0.03	0.00	0.10	0.01	0.85	0.04	0.65	0.02	1.64
Goodland	0.02	0.00	0.08	0.00	0.81	0.00	0.55	0.00	1.46
Heyer#12	0.04	0.00	0.09	0.01	1.04	0.05	0.46	0.03	1.63
Norland	0.02	0.00	0.10	0.01	0.54	0.03	0.50	0.02	1.16
PF #36	0.02	0.00	0.08	0.00	0.36	0.02	0.39	0.01	0.85
PF #50	0.02	0.00	0.03	0.00	0.86	0.01	0.55	0.01	1.46
PF #51	0.02	0.00	0.02	0.00	0.62	0.03	0.45	0.02	1.11
Westland	0.03	0.00	0.06	0.00	1.10	0.00	0.38	0.02	1.57
S-Gold	0.09	0.00	¹ ND	ND	0.45	0.00	0.68	0.04	1.19
Blend #1	0.03	0.00	0.10	0.00	0.61	0.01	0.52	0.01	1.26
Blend #4	0.02	0.00	0.09	0.00	0.70	0.14	0.52	0.00	1.33

¹ND indicates not detected

Appendix 14.

Analysis of variance for fermented aroma in apple juice

Source	DF	Sum of Squares	F Value
Pan	8	2411.14	4.20 **
Cul	9	3920.56	6.07 **
Rep	1	572.45	7.98 **
Pan*Cul	72	7088.20	1.37
Pan*Rep	8	517.30	0.90
Cul*Rep	9	470.16	0.73

** indicates F values are significant at $p = 0.05$

Appendix 15

Mean scores of replicates for fermented
aroma in apple juice

Rep	N	Mean ¹
1	90	16.20 a
2	90	12.62 b

¹scores with the same letter are not
significantly different ($p=.05$)

Appendix 16.

Analysis of variance for apple aroma in apple juice

Source	DF	Sum of Squares	F value
Pan	8	5089.20	12.01 **
Cul	9	2650.31	5.56 **
Rep	1	27.22	0.51
Pan*Cul	72	6353.70	1.67 **
Pan*Rep	8	474.0	1.12
Cul*Rep	9	1099.11	2.31 **

** indicates F values are significant at $p = 0.05$

Appendix 17.

Analysis of variance for apple flavor in apple juice

Source	DF	Sum of Squares	F values
Cul	9	5982.50	8.23 **
Pan	8	14486.64	22.42 **
Rep	1	3.20	0.04
Cul*Pan	72	6083.13	1.05
Cul*Rep	9	598.80	0.82
Pan*Rep	8	737.40	1.14

** indicates F values are significant at $p = 0.05$

Appendix 18.

Analysis of variance for sweetness in apple juice

Source	DF	Sum of Squares	F values
Cul	9	18765.38	44.32 **
Pan	8	1074.80	2.86 **
Rep	1	301.60	6.41 **
Cul*Pan	72	4248.60	1.25
Cul*Rep	9	730.67	1.73
Pan*Rep	8	166.04	0.44

** indicates F values are significant at $p = 0.05$

Appendix 19.

Mean cultivar scores for sweetness versus total sugar content
determined by Official methods and HPLC analysis

Cultivar	Sensory Score	A.O.A.C. (% Sucrose)	HPLC Total Sugar (% Sucrose)
Kerr	12.88	12.55	10.11
Breakey	16.94	7.07	9.88
Collet	19.33	11.06	9.82
Goodland	13.38	12.40	10.15
Heyer #12	9.77	8.50	7.53
Norland	30.32	10.50	8.60
PF #36	27.72	10.94	7.19
PF #50	11.99	11.44	8.93
PF #51	39.83	11.30	9.17
Westland	4.94	8.31	6.80

Appendix 20.

Analysis of variance for sourness in apple juice

Source	DF	Sum of Squares	F value
Cul	9	34292.20	118.70 **
Pan	8	1779.21	6.93 **
Rep	1	13.90	0.43
Cul*Pan	72	5250.90	2.27 **
Cul*Rep	9	1250.44	4.33 **
Pan*Rep	8	312.41	1.22

** indicates F values are significant at $p = 0.05$

Appendix 21.

Mean cultivar scores for sourness versus total acidity
determined by Official methods and HPLC analysis

Cultivar	Sensory Score	A.O.A.C. (% Malic Acid)	HPLC (% Malic Acid)
Kerr	46.39	1.01	0.68
Breakey	28.72	0.44	0.76
Collet	38.83	0.70	0.85
Goodland	44.21	0.88	0.81
Heyer #12	44.38	0.91	1.04
Norland	19.00	0.50	0.54
PF #36	16.38	0.39	0.36
PF #50	42.50	0.81	0.86
PF #51	11.88	0.47	0.62
Westland	53.88	1.05	1.10

Appendix 22

Analysis of variance for astringency in apple juice

Source	DF	Sum of Squares	F value
Cul	9	15310.53	35.74 **
Pan	8	3456.30	9.08 **
Rep	1	21.36	0.45
Cul*Pan	72	6999.20	2.04 **
Cul*Rep	9	666.53	1.56
Pan*Rep	8	300.74	0.79

** indicates F values are significant at $p = 0.05$

Appendix 23.

Mean cultivar scores for astringency versus total phenolics
determined by Official methods

Cultivar	Sensory Score	A.O.A.C. (% Tannic Acid)
Kerr	41.61	0.09
Breakey	32.94	0.07
Collet	38.49	0.08
Goodland	42.83	0.11
Heyer #12	41.50	0.09
Norland	23.38	0.05
PF #36	22.44	0.18
PF #50	39.00	0.10
PF #51	16.33	0.09
Westland	41.32	0.06

Appendix 24.

Mean cultivar scores for sweetness and sourness versus
sugar - acid ratio (A.O.A.C)

Cultivar	Sensory		Sugar-Acid ratio
	Sweetness	Sourness	
Kerr	12.88	46.39	12.40
Breakey	16.94	28.72	16.07
Collet	19.33	38.83	15.80
Goodland	13.38	44.21	14.17
Heyer #12	9.77	44.38	9.35
Norland	30.32	19.00	21.00
PF #36	27.72	16.38	28.05
PF #50	11.99	42.50	14.12
PF #51	39.83	11.88	24.05
Westland	4.94	53.88	7.91