

Contents

List of Figures	III
List of Tables	VI
List of Abbreviations	VII
1 Introduction	1
2 Shrink sleeves and plastic bottle recycling: State of the art	3
2.1 Shrink sleeves	3
2.1.1 Materials	4
2.1.2 Production and shrink process	6
2.2 Overview of plastic bottles	7
2.3 Mechanical recycling of plastic bottles	9
2.3.1 Collection	9
2.3.2 Preenrichment in sorting plants	10
2.3.3 Refinement in recycling plants	12
2.4 Influence of shrink sleeves on bottle recycling process	12
3 Near Infrared (NIR) spectroscopy	15
3.1 Physical principle	15
3.1.1 Vibrational spectroscopy	15
3.1.2 NIR-sensitive functionalities	17
3.1.3 Application in polymer identification	18
3.2 Data acquisition	18
3.2.1 NIR light sources	18
3.2.2 NIR detectors	20
3.3 Data analysis	20
3.3.1 Data preprocessing	21
3.3.2 Data classification	26
3.4 Limitation of NIR in polymer sorting	26
4 Machine learning for classification	29
4.1 Decision tree	31
4.1.1 Algorithms to construct decision trees	31
4.1.2 Random forest	34
4.2 Support vector machine (SVM)	34
4.2.1 Binary classification	34
4.2.2 Multiclass SVM	36
4.3 Partial least squares (PLS)	36

4.3.1	Linear PLS	37
4.3.2	Nonlinear PLS	38
4.3.3	PLS for classification	38
4.4	Convolutional neural network (CNN)	40
4.4.1	Common artificial neural network (ANN)	40
4.4.2	Architecture of CNN	42
4.5	Application in NIR spectroscopy	44
5	Material and methods	47
5.1	Material selection	47
5.1.1	LWP sample set	47
5.1.2	Reference sample set	47
5.1.3	Post-consumer bottles	49
5.2	Spectra acquisition	51
5.3	Data preprocessing	52
5.3.1	Spectra extraction	52
5.3.2	Spectra preprocessing	53
5.4	Machine learning algorithms	54
5.4.1	Implementation	55
5.4.2	Hyperparameter optimization	57
6	Results and discussion	61
6.1	Training and selection of classification models	61
6.1.1	Training of model set T1	61
6.1.2	Training of model set T2	65
6.2	Classification of reference bottles	67
6.2.1	Difference in classification algorithms	67
6.2.2	Influence of bottle and sleeve parameters	72
6.3	Classification of post-consumer bottles	80
6.3.1	Classifiers in model set T1	81
6.3.2	Classifiers in model set T2	83
6.3.3	Non-detectable cases	85
7	Conclusion and outlook	91