

Operational challenges in the mechanical recycling of polymer waste: the effect of feedstock variability on process stability and regranulate quality

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Abstract:

Mechanical recycling is the principal route for material recovery from thermoplastic waste, but variable feedstock complicates stable operation and repeatable regranulate quality. This critical narrative review links material history and contamination to process response, distinguishing post-consumer recycle (PCR), post-industrial waste and controlled virgin-polymer studies. Particular attention is given to mutual contamination among polypropylene (PP), high-density polyethylene (HDPE) and polyethylene terephthalate (PET) streams, and to degradation of PP and polyethylene (PE), including low-density polyethylene (LDPE). Comparative synthesis shows that changes in melt flow rate (MFR), more precisely melt mass-flow rate, must be interpreted with polymer grade, stabilisation and measurement conditions specified. Process stability is understood as maintaining operating parameters and product properties within specified limits despite feedstock variability. The review also distinguishes metered electricity consumption from life-cycle cumulative energy demand and separates composition prediction from demonstrated adaptive control. Process monitoring and machine learning offer promising diagnostic tools, but their reported performance is conditional on the materials and operating conditions investigated. The contribution is a framework connecting feedstock, process signals and product quality while identifying limits to transfer between laboratory and industrial evidence.

Keywords: mechanical recycling; polymer waste; post-consumer recycle; polymer degradation; extrusion; process stability



1. Introduction

Polymer materials are among the basic materials used in packaging, the automotive industry, construction, electronics and the manufacture of consumer goods. Their widespread use, however, generates a large waste stream. According to Eurostat, an average of 35.3 kg of plastic packaging waste per capita was generated in the European Union in 2023, of which 14.8 kg was recycled [1]. At the same time, the share of secondary plastics produced or recycled in the EU increased from 6.9% of total plastics consumption in 2018 to 12.1% in 2022 [2].

The importance of recyclates will also increase under the influence of regulation. Regulation (EU) 2025/40 on packaging and packaging waste introduces minimum post-consumer recycled plastic content levels from 2030, including 30% for selected polyethylene terephthalate (PET) packaging and single-use beverage bottles, and 35% for certain other plastic packaging [3]. Ensuring an adequate supply of post-consumer recycle (PCR) is therefore becoming not only an environmental issue but also a technological one.

Mechanical recycling is currently the most widely used route for reusing thermoplastics. A typical process includes sorting, shredding, washing, drying, extrusion, melt filtration and pelletising. Unlike virgin polymer, however, the input material originates from many products with different service histories. Real PCR streams are heterogeneous, partly degraded and contaminated, and their composition can vary between successive batches [4], [5].

This problem is particularly important under industrial conditions. Laboratory materials are often prepared from controlled, homogeneous streams, whereas real waste contains mixtures of different polymers, additives and contaminants. Ximenis et al. identify this discrepancy as one of the major constraints on scaling recycling technologies from laboratory to industrial conditions [6].

From an operational perspective, the fundamental challenge is therefore not only whether a polymer can be remelted, but whether a stable process can be maintained with variable feedstock and a regranulate with repeatable properties can be obtained. Here, process stability means the ability to maintain operating parameters and product properties within specified, application-dependent limits despite variability in the input material. The aim of this article is to review and critically analyse international research on how polymer waste variability affects degradation, process stability and regranulate quality. The analysis focuses on polypropylene (PP) and polyethylene (PE), particularly high-density polyethylene (HDPE) and low-density polyethylene (LDPE), together with the influence of PET contamination. Separate attention is given to process parameters and in-line monitoring for assessing feedstock changes.

The contribution of the review is an integrated, condition-dependent synthesis linking feedstock origin and material history to observable machine responses and product quality. Compared with reviews centred on mixed-plastic challenges [5], degradation pathways [15] or packaging recycling [16], it explicitly separates model-material evidence from real waste-stream evidence and compares the interpretative limits of process signals, energy indicators and predictive monitoring. This provides an operational framework for assessing transferability; it does not claim new experimental measurements or a validated universal control model.

2. Materials and Method

This article is a structured critical narrative review, rather than a systematic review or meta-analysis. Its organisation follows the review-methodology guidance of Snyder [7]. PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [8] is used only as guidance for reporting the information sources, search concepts, eligibility criteria and approach to synthesis; compliance with the complete PRISMA checklist is not claimed. The article does not provide a registered protocol,



complete database search histories or screening counts, so its coverage should not be interpreted as exhaustive or fully reproducible.

The literature sources reported for the review comprise Scopus and Web of Science, the ScienceDirect, SpringerLink, Wiley Online Library, ACS and RSC publisher platforms, and supplementary Google Scholar searches. The core publication period is 2015–2026, with emphasis on 2021–2026. Eligible research concerns mechanical reprocessing of thermoplastics and reports identifiable feedstock together with composition, ageing, degradation, rheological, mechanical, energy or process-monitoring outcomes. Reviews support the conceptual background; official statistics and legislation support the introduction.

Search concepts combine “mechanical recycling”, “polymer waste” or “post-consumer recyclate” with “feedstock variability”, “cross-contamination”, “polymer degradation”, “repeated extrusion”, “rheology”, “MFR”, “energy consumption” or “in-line monitoring”, and polymer names such as PP and HDPE. Selection is relevance-based, giving priority to experimental evidence on real PCR and to controlled studies that isolate contamination or degradation mechanisms. Studies devoted solely to chemical conversion or thermal recovery, without a mechanical-recycling comparison, fall outside the scope. Evidence is synthesised by material origin, matrix and contaminant composition, ageing history, processing conditions and scale. Numerical results are interpreted within their original test conditions and are not pooled across studies.

3. Results

3.1. Sources of PCR variability

PCR is not a simple equivalent of virgin polymer. Its properties result from the original characteristics of the plastic, product manufacturing conditions, duration and manner of use, environmental degradation, collection, sorting and any previous processing cycles. Muzata et al. identify the presence of chemically different plastics in varying proportions in mixed post-consumer streams as one of the main barriers to mechanical recycling [5].

Even a stream classified as a single polymer may contain grades with different molar masses, melt flow rates (MFRs), comonomer contents or additives. MFR, more precisely melt mass-flow rate, is a measure of flow under specified temperature and load. PCR also contains pigments, stabilisers, mineral fillers, residues of labels and adhesives, and substances introduced during use. Tranchida et al. indicate that recycled-polyolefin microstructure and composition require several complementary characterisation methods [9].

Service history is an additional source of heterogeneity. Ultraviolet radiation, oxygen, temperature and mechanical loading may alter macromolecular structure before a product is sent for recycling. Surface components also enter the stream. For example, Lisiecki et al. showed that binders and pigments from inks on LDPE films may affect processability, mechanical properties, colour and the emission of volatile compounds during reprocessing [10].

The principal differences between virgin feedstock and PCR are summarised in Table 1.



Table 1. Characteristics of virgin feedstock and PCR

Characteristic	Virgin polymer	PCR
Composition	Controlled	Variable
Molecular weight	Specified range	Dependent on material history
MFR	Stable for a given grade	Potentially substantial variability
Thermal history	Known	Often unknown
Degree of degradation	Low/controlled	Variable
Contaminants	Limited	Organic, mineral and polymeric
Additives	Known package	Different types and degrees of depletion
Batch repeatability	High	Batch-to-batch variability

Source: author synthesis based on [4], [5] and [9]. The comparison describes general tendencies; virgin grades also differ, and sorting or blending may improve PCR consistency. MFR comparisons require identical test temperature and load.

From an industrial perspective, batch-to-batch variability is one of the most important problems. A change in PCR batch can simultaneously alter viscosity, MFR, ash content, the fraction of foreign polymer and the degree of degradation. Patel et al. emphasise that polymer identification alone is insufficient to define the quality of a material intended for reprocessing; its degree of degradation must also be considered [4].

3.2. Mutual contamination among PP, HDPE and PET streams

Complete polymer separation is difficult in real plants. Near-infrared (NIR) spectroscopy enables rapid identification of the main plastics groups, but its effectiveness is limited by factors including surface condition, pigments, multi-material structures and the similarity of the spectra of some plastics [11]. Neo et al. therefore identify a need for hybrid methods that combine different spectroscopic techniques with data-analysis algorithms [11].

The separation of polyolefins is a particular problem. PP and PE are chemically similar but do not form fully compatible blends. Sutliff et al. showed that conventional NIR methods separate polyolefins from many other plastics relatively well, whereas identifying individual polyolefins is substantially more difficult. Machine learning improved their classification performance [12].

Patel, Billington and Shaver studied reciprocal contamination in PP-rich and HDPE-rich packaging-grade model blends [13]. Their results show that low-level contamination is more damaging to PP than to HDPE, reflecting phase separation and composition-dependent degradation. Rheology also provided a means of resolving HDPE content in PP at approximately one percentage point in the investigated calibration system [13]. This is a study-specific analytical capability, rather than a universal contamination tolerance or an established accuracy for heterogeneous industrial PCR.

Gnoffo, Arrigo and Frache examined virgin HDPE model systems containing 10% PP by mass, or 10% PP and 2% PET by mass [14]. Specimens underwent either photo-oxidative ageing for 300 h at 60°C in air (UV irradiance 90 W/m²) or thermo-oxidative ageing for 300 h at 80°C and 100% relative humidity, followed by twin-screw reprocessing at 250°C and 100 rpm. Contamination particularly reduced HDPE ductility after thermo-oxidative ageing, whereas degradation was the main embrittlement



factor in photo-aged specimens [14]. These controlled formulations simulate packaging contamination; they are not measurements of an actual mixed PCR stream.

These results show that contamination levels cannot be interpreted independently of matrix type and material history. In practice, the same percentage of foreign polymer may have different effects on the process and product properties when PCR exhibits a different degree of prior degradation.

3.3. Degradation during repeated mechanical recycling

Each mechanical recycling cycle exposes the material again to temperature, oxygen and shear stresses. Thermal, thermo-oxidative and mechanical degradation may then occur and overlap with the earlier photo-oxidative ageing experienced during use. Ceretti et al. indicate that the direction of change depends not only on process parameters but also on polymer chemistry, molar mass and the stabilisation system [15].

The principal mechanisms include chain scission, branching and crosslinking. In PP, chain shortening generally lowers molar mass and viscosity and increases melt flow rate (MFR), more precisely termed melt mass-flow rate. MFR is the mass extruded through a specified die over 10 min under a specified temperature and load; comparisons therefore require the same test conditions. In PE, chain scission, branching and recombination compete, so the direction of rheological change depends on grade, stabilisation and processing history [16].

Von Vacano et al. examined stabilised and unstabilised, elastomer-modified PP compounds containing talc over up to 30 extrusion passes at 260°C and 60 rpm in air [17]. Their combined experimental and simulation analysis supports coupled random and shear-induced chain cleavage, with stabilisation delaying molecular damage. This strengthens the mechanistic interpretation of PP degradation while showing why stabiliser state must accompany any reported recycling-cycle count.

Felgel-Farnholz et al. compared HDPE, linear low-density polyethylene (LLDPE) and LDPE in prolonged extrusion experiments, including unstabilised materials and formulations containing phenolic and phosphite stabilisers [18]. Together with the grade-dependent results discussed below, this highlights polymer architecture and stabilisation as essential comparison variables. Polyethylene cannot be assigned a universal direction of molar-mass or viscosity change merely from its polymer name.

Akhras et al. investigated six laboratory reprocessing cycles, each including extrusion, pelletising, injection moulding and milling, using four initially virgin commercial grades: thermoforming PP (PP-TF), injection-moulding PP (PP-MO), HDPE and LDPE [19]. The use phase and external contamination were excluded, and no re-stabilisation was applied. Molar mass was assessed by high-temperature gel permeation chromatography. MFR was measured at 230°C for PP and 190°C for PE, under a 2.16 kg load [19].

After six cycles, the weight-average molar mass (M_w) of PP-TF and PP-MO decreased by approximately 39% and 47%, respectively; their MFR increased by factors of approximately 3.3 and 4.6. LDPE showed an approximately 21% increase in M_w and a 35% decrease in MFR. HDPE exhibited little change in M_w and an approximately 7.5% decrease in MFR [19]. Table 2 summarises these grade-specific trends; they should not be read as universal trajectories for real PCR.



Table 2. Grade-specific trends after six controlled reprocessing cycles [19]

Polymer / grade	Observed mechanism	MFR after six cycles	Rheological implication
PP-TF / PP-MO	Chain scission	$\times 3.3 / \times 4.6$	Lower viscosity
HDPE	Competing scission and branching	Approximately -7.5%	Small change for this grade
LDPE	Branching / crosslinking	Approximately -35%	Higher viscosity

Source: [19]. Initially virgin grades; six extrusion–injection moulding–milling cycles, without use-phase ageing, added contamination or re-stabilisation. MFR: PP 230°C/2.16 kg; HDPE and LDPE 190°C/2.16 kg. These results apply to the specified grades and protocol.

Depletion of stabilisation can also reduce resistance to subsequent processing, even when current material properties remain acceptable [15], [17]. Recyclability therefore cannot be assessed solely from the current MFR value or mechanical properties.

Studies of initially virgin polymers under controlled cycles isolate processing effects but do not reproduce the full complexity of PCR. In industrial waste streams, processing-induced degradation overlaps with prior ageing and contamination.

Regranulate behaviour reflects the cumulative history of manufacture, use and ageing, collection and sorting, residual contamination, recycling and subsequent reuse. Each further cycle adds to this history.

3.4. Effect of feedstock variability on process stability

3.4.1. Temperature, pressure and extruder load

Changes in molecular weight and material viscosity directly affect resistance to flow in the extruder. As a result, successive PCR batches processed with identical setpoints may require different torque, generate different pressures and reach different melt temperatures.

Fischer et al. studied six consecutive batches of household HDPE PCR, using film extrusion and injection moulding [20]. In the injection-moulding tests, batches 2 and 3 required peak pressures of 1304 and 1111 bar (130.4 and 111.1 MPa), respectively, for the tension-rod geometry, a reported difference of approximately 20%; the casing geometry showed approximately 10%. Thus, the 20% result concerns injection pressure and is geometry-dependent, not a directly measured extrusion-pressure difference. MFR was determined at 190°C and 230°C under a 5 kg load, before and after drying. The batch differences illustrate the operational importance of composition and viscosity [20].

Akhras et al. investigated an industrial extrusion system processing post-industrial flakes from pigmented PP/PE multilayer films used for furniture surfaces, with substantial inorganic filler content [21]. Across the tested filtration and degassing configurations, increasing screw speed from 150 to 250 rpm raised mean melt temperature by approximately 18°C and was associated with higher MFR, measured at 230°C/2.16 kg. This result reflects viscous heating and the studied material and machine configurations; it does not establish the same temperature response for household PCR. The separate constant-setting trial operated at 230 rpm and approximately 510 kg/h [21].

The long-term HDPE reprocessing experiments of Oblak et al. comprised 100 successive extrusion cycles and tracked changes in processability and mechanical properties [22]. This accelerated controlled history is distinct from seasonal changes in incoming PCR batches. It supports the need to consider



competing degradation mechanisms, while the number of cycles alone cannot define the lifetime of an industrial recycle.

From an operational perspective, torque, current draw and power can therefore act as indirect indicators of changes in feedstock properties. Their interpretation nevertheless requires simultaneous analysis of temperature, pressure and actual throughput because an increase in load may be caused by either higher viscosity or a change in system fill level.

3.4.2. Throughput and melt filtration

Process stability also depends on the physical form of the waste. Unlike regular virgin pellets, PCR may be present as flakes or regrind with variable shape, size and bulk density. Unstable feeding changes screw fill, residence time, pressure and actual throughput in kg/h.

Filtration is the second key element. Even effective sorting and washing do not remove every solid particle. Koller, Paulik and Burgstaller showed that the rate of pressure rise upstream of the filter depends not only on the mass fraction of contaminants but also on their size, surface area and deformability [23]. Fine particles may block the filter surface more rapidly, whereas soft contaminants require finer screens than rigid particles of a similar size.

Finer filtration does not always yield an unequivocally better process. In an analysis of acrylonitrile butadiene styrene (ABS) PCR, Liedl and Burgstaller found that reducing filter mesh size improved contaminant removal but simultaneously increased pressure, stoppage frequency, material losses and additional thermal loading [24]. This evidence from ABS illustrates a filtration trade-off; its numerical magnitude should not be transferred directly to polyolefin streams.

The relationships among feedstock, process response and product quality are coupled rather than strictly one-directional.

A composition change can alter melt rheology and therefore pressure or torque. Depending on operating conditions, this can change melt temperature, throughput and thermomechanical exposure, influencing regranulate properties. Changes in feeding or filter resistance can produce similar signals, so attribution requires several measurements considered together.

Plant operating parameters should therefore not be treated solely as control values. They also constitute a set of signals that may reveal changes in the input material.

4. Discussion

4.1. Rheological and mechanical properties

MFR is commonly used for rapid assessment of regranulate processability. Some publications use the name melt flow index (MFI) for this quantity; this review uses MFR consistently except when identifying the terminology of a cited study. MFR reflects the original grade, degradation, foreign polymers and additives. An increase may indicate chain shortening, whereas a decrease may reflect branching or crosslinking; neither direction identifies the cause uniquely.

Patel et al. therefore proposed a broader approach to defining PE quality by quantifying degradation through rheology [4]. The authors showed that rheological measurements can provide information not only about current material behaviour but also about its susceptibility to further change during processing.

Cross-contamination further complicates the relationship between MFR and performance properties. A material may have an acceptable flow index while exhibiting lower ductility or impact strength because of phase incompatibility. Consequently, the assessment of high-quality PCR should include at least a combination of composition, rheology and mechanical-property characterisation.



In industrial applications, repeatability between batches is as important as mean parameter values. Regranulate whose MFR or mechanical properties vary substantially over time forces frequent setpoint corrections at the customer's plant and limits the extent to which virgin polymer can be replaced.

4.2. Process energy demand

Material variability also affects process energy demand. Electricity is consumed by heaters, drives and auxiliary systems. Leherbauer et al. modelled electricity consumption in recycling extrusion by distinguishing heat losses, inter-zone heat transfer and individual machine components [25]. Metered electricity consumption is an inventory quantity expressed in kWh over a defined period or process boundary.

Specific electricity consumption (SEC) is obtained by dividing that electricity consumption by the mass processed or the mass of saleable reggranulate; the denominator and system boundary should always be stated. It may be expressed in kWh/t and depends on throughput as well as equipment operation. Start-up and stoppages can inflate short-test SEC relative to continuous operation. Cumulative energy demand (CED), in contrast, is a life-cycle assessment (LCA) indicator of primary energy associated with the energy and material inputs within the specified boundary, commonly expressed in MJ/kg or GJ/t. It is not identical to directly metered electricity consumption [25], [26].

Bozdoğan, Tutumlu and Atmaca combined twelve months of meter-based operating data from a plant processing PET, HDPE, LDPE and PP with a gate-to-gate LCA [26]. Extrusion accounted for 72–79% of calculated CED within that recycling assessment, rather than 72–79% of the full product life cycle or necessarily the same share of metered electricity. A modelled scenario combining efficient extrusion and sensor-based sorting predicted reductions of up to 17.6% in CED and 18.1% in global warming potential (GWP). These are scenario estimates relative to the measured baseline, not measured savings following an implemented upgrade [26].

The evidence identifies extrusion as an energy hotspot within the studied boundaries. Better feedstock control may improve quality and energy performance, but a measured causal reduction in SEC cannot be inferred from an LCA optimisation scenario alone. Such a claim requires a comparable operating baseline and subsequent plant measurements.

4.3. In-line monitoring and data analysis

Increasing PCR variability means that conventional quality control based on sampling successive batches may not be sufficient for a rapid response to feedstock changes. In-line monitoring and the use of data generated by the plant itself are therefore becoming increasingly important.

Teruel et al. used historical PP recycling data to predict melt flow index (MFI, corresponding to MFR terminology), ash content, impact strength and shrinkage, and developed a tool for selecting input batches to reduce variability in target properties [27]. This is a batch-composition and planning approach: it complements homogenisation but does not itself demonstrate continuous feedback control of an extruder.

Kang, Kim and Ahn reported 96% composition-classification accuracy from 10 s segments of a single extrusion-pressure signal [28]. The compositions differed in steps of 10 percentage points by mass, and processing conditions were held constant. This is classification among the investigated compositions, not 96% accuracy in continuously quantifying arbitrary contamination levels. The result supports a proof of concept for a soft sensor, meaning an estimate of a material property from process signals. Its transfer to variable industrial PCR requires validation across changes in settings, throughput, degradation and sensor conditions.



Composition diagnosis and adaptive process control require separate validation. A prospective control system would combine several process measurements with independent material-quality checks.

Temperature, pressure, torque, power and throughput would first support detection of a change; a validated model could then estimate composition or product properties. A control policy would subsequently select a parameter correction or product classification, with measured product quality used to check the outcome.

This framework is consistent with Industry 4.0, but composition-classification performance alone does not establish control effectiveness. Demonstrating adaptive control would require closed-loop tests against fixed settings, using specified limits for product quality, process variability and energy consumption. The cited prediction studies [27], [28] support individual elements of that framework rather than proving its complete industrial implementation.

4.4. Comparison and transferability of the evidence

The key studies agree that flow behaviour, material history and composition must be considered together, but they address different sources of variability (Table 3). Controlled reprocessing [19] isolates cumulative processing damage; real PCR batch analysis [20] combines composition, grade and previous history; post-industrial trials [21] demonstrate machine-scale responses for a different waste origin. Their numerical results are complementary, rather than interchangeable.

Table 3. Comparison of representative studies and limits of transfer to industrial PCR

Study	Material origin and composition	Ageing / processing and scale	Finding and transfer limitation
Patel et al. [13]	Defined PP/HDPE packaging-grade blends	Laboratory characterisation and rheological assessment of degradation	Asymmetric contamination effects; composition calibration is specific to the studied blends.
Gnoffo et al. [14]	Virgin HDPE; 10% PP, or 10% PP + 2% PET by mass	300 h photo- or thermo-oxidation; laboratory twin-screw reprocessing, 250 °C, 100 rpm	Ageing changes the contamination response; model blends do not represent the full PCR distribution.
Akhras et al. [19]	Initially virgin PP-TF, PP-MO, HDPE and LDPE	Six laboratory extrusion / moulding cycles; no use phase or re-stabilisation	Different grade-specific Mw and MFR trends; isolates processing rather than real waste history.
Fischer et al. [20]	Six consecutive household HDPE PCR batches; residual PP	Film extrusion and injection-moulding trials; prior service history not controlled	Batch-dependent process and product changes; cited 20% pressure difference is from injection moulding.
Akhras et al. [21]	Post-industrial, filled and pigmented PP/PE multilayer flakes	Industrial recycling extruder; varied screw speed, filtration and degassing	Screw speed affects melt temperature and MFR; filler-rich material differs from household PCR.
Bozdoğan et al. [26]	Industrial PET, HDPE, LDPE and PP recycling	12 months of plant data; gate-to-gate LCA and modelled upgrades	Extrusion dominates calculated CED; scenario savings require implementation and measurement to confirm.



Study	Material origin and composition	Ageing / processing and scale	Finding and transfer limitation
Kang et al. [28]	Controlled polymer compositions in 10-percentage-point mass steps	Extrusion at constant conditions; single pressure sensor	96% classification from 10 s signals; variable settings and closed-loop control need separate validation.

Source: author comparison of [13], [14], [19]–[21], [26] and [28]. Only the conditions needed to interpret the findings are shown; the table is not a quantitative ranking of studies.

Agreement at the mechanism level does not imply agreement in the magnitude of property change. The limited HDPE change after six cycles [19], for example, cannot negate damage under a much longer history [22] or in formulations with different stabilisation [18]. Likewise, the deleterious effect of contamination on mechanical properties [13], [14] can coexist with useful correlations between viscosity and process signals [20], because acceptable flow does not ensure ductility or impact resistance.

A transferable assessment should therefore report feedstock origin and matrix, foreign-polymer and filler content, ageing and stabiliser history, measurement temperature and load, equipment configuration and actual throughput. Composition diagnosis should be checked against independent material analysis, and adaptive control against measured process and product outcomes. This separates an observed correlation, a predictive model and a demonstrated operating improvement.

5. Conclusions

The analysis of current literature indicates that one of the fundamental limitations of mechanical recycling of polymer waste is not the ability to plasticise it again, but the ability to ensure process stability and repeatable regrenulate quality with variable feedstock. Real PCR differs in polymer type and grade, use and processing history, degree of degradation, and additive and contaminant content.

Mutual polymer contamination must be evaluated with the matrix and previous ageing history specified. Reciprocal PP/HDPE contamination and HDPE model blends containing 10% PP, with or without 2% PET by mass, show composition- and history-dependent effects on degradation and mechanical behaviour [13], [14]. A single contamination threshold cannot be transferred across polymers or applications.

Repeated processing does not cause identical changes in every polyolefin. PP commonly shows chain scission and increasing MFR, whereas PE may exhibit competing scission, branching and crosslinking. Grade, stabiliser content and processing history determine the observed balance [15]–[19].

Changes in feedstock properties can be reflected in operating signals, but their interpretation is process-specific. Extrusion torque and pressure must be distinguished from injection-moulding pressure; melt temperature depends on viscous heating as well as heater settings; and contaminant characteristics affect filtration resistance. Several signals and independent material measurements are required to identify the cause of a process change.

Integrating feedstock characterisation, batch management and process monitoring is a promising development direction. Current prediction and classification studies support this approach, but they do not by themselves establish the effectiveness of adaptive control. Industrial implementation requires validation under changing feedstock and operating conditions, with product quality and energy demand assessed against a defined baseline.



This narrative review is limited by relevance-based literature selection, incomplete search documentation and heterogeneous test conditions. Findings from model blends, commercial virgin grades, post-industrial waste and real PCR are not directly interchangeable; numerical values should be transferred only after checking matrix composition, ageing, measurement conditions and machine scale. Future long-term industrial studies should link material characterisation, continuous operating signals, SEC and successive regranulate properties to quantify feedstock–process–product relationships.

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