"Exergy-based Sustainability Assessment of Batch versus Continuous Tabletting in Pharmaceutical Formulation"

This study approaches the environmental sustainability of batch versus continuous granulation-based tablet manufacturing from a resource point of view by conducting *Exergy Analysis* (EA) and *Exergetic Life Cycle Analysis* (ELCA) at three different levels in order to identify and locate resource losses through the pharmaceutical production chain. Exergy analysis is performed at both process (α) and plant (β) level (Janssen-Cilag NV pharmaceutical manufacturing plant at Latina, Italy), while the CEENE method (*Cumulative Exergy Extraction from the Natural Environment*) is used in a cradle-to-gate approach at the overall industrial level (γ). Shifting from batch to continuous production resulted in an exergetic resource consumption reduction of 10.19% (65.6 to 58.9 kJ_{ex}/tablet), 15.21% (111 to 94.0 kJ_{ex}/tablet) and 2.38% (2.14 to 2.08 MJ_{ex}/tablet) at respectively process (α), plant (β) and overall industrial level (γ). Focussing on drug production processes by excluding API and packaging material constituents (transitting exergy) resulted in a reduction of 33.99% (19.1 to 12.6 kJ_{ex}/tablet), 25.89% (64.6 to 47.7 kJ_{ex}/tablet) and 14.69% (138 to 118 kJ_{ex}/tablet) on the respective boundary systems. The results apply to high dose drugs (high API weight percentage). For low dose drugs (total API percentage of less than 50%), sensitivity analysis showed a reduction in resource consumption of 38% within the cradle-to-gate approach (γ). Extensions to the scope of this study resulted in including packaging as well as distribution phases to assess the impact within the total pharmaceutical production chain. At γ level, natural resources for packaging materials proved to be dominated by its land demand, while natural resources for the API production as well as drug product production processes and distribution and transport processes were dominated by fossil resources. From an emission point of view, the plant's carbon *Ecological Footprint* proved to be reduced by 10.10% (2 883 to 2 592 ha.a) when shifting the plant's yearly tablet manufacturing from batch to continuous production.

Auteurs UGent: Wouter De Soete, Jo Dewulf
Auteurs Janssen Pharmaceutica NV: Philippe Cappuyns, Geert Van der Vorst, Bert Heirman, Wim Aelterman
Auteurs GEA Pharma Systems - Collette™: Kris Schoeters