Chapter N 039

The ILCIDAF project for the development of an Italian Database of Life Cycle Inventory of agri-food products: the wheat milling phase

**Abstract.** The project 'Italian Life Cycle Inventory Database of Agri-Food Products' (ILCIDAF), funded by the Ministry of University and Research (PRIN, 2017), aims to promote the sustainability of the agri-food sector through the development of an Italian database for some important food chains in our country (bread and pasta, wine, olive oil and citrus fruits). The research project is being developed by four scientific units: the University of Bari, Chieti-Pescara, Messina and Reggio Calabria, respectively. The database is constructed considering the entire supply chain of the indicated foodstuffs. In particular, in this work, the milling activities of durum and soft wheat are analysed and the construction of datasets related to the production phase of durum and soft wheat flour is proposed.

**Keywords.** Milling, Wheat, Database, Flour, Semolina, Bread, Pasta

## Introduction

The Project of Relevant National Interest (PRIN 2017) titled “Promoting Agri Food Sustainability: Development of an Italian Life Cycle Inventory Database of Agri-Food Products” (ILCIDAF) aims to build a database dedicated to the Italian agri-food sector. The Database is structured in such a way as to describe all phases of a food production chain: the agricultural phase of cultivation, the industrial phase of transformation of intermediate and final products. In this paper, the supply chain of wheat products will be discussed, with particular focus on the wheat milling phase in order to build datasets on the production phase of durum and soft wheat flour. In commercial databases, there is no characterisation for the different flour classes that exist. Agribalyse describes only for French soft wheat the 5 different types. The ILCIDAF project, on the other hand, provides 8 different types of flour: 3 for durum wheat (semolina, semolate, wholemeal semolina); 5 for soft wheat (type 00, 0, 1, 2 and wholemeal flour).

The milling process is essential for the production of durum and soft wheat flour necessary for the production of pasta and bread. Once harvested, the wheat is separated from extraneous substances (stones, soil, metal residues), then transported and stored at controlled temperatures to promote slow drying. Before being milled, the grains are further cleaned to remove plant residues and soaked (conditioning) to facilitate grain crushing. Subsequently, the milling process consists of several steps: crushing of the grains, husking and regrinding. Finally, sifting (by means of a plansifter device) before entering the cylinders (or rolling mills), allows for the classification and selection of the products before they are subjected to grinding again or arrive at the semolina mill for the sifting process.

## Literature review

The data relating to the wheat milling phase, studied in this work, are the result of a literature analysis with the aim of acquiring data on the use of resources (energy consumption, water resources), input flows (type of wheat) and output flows from the system (type of flour, co-products, waste). The bibliographic collection concerned:

1. Scientific articles published in journals: 11 articles were selected (Table 1), of which 6 related to durum wheat and 5 to soft wheat;
2. Italian EPDs related to the production of “uncooked pasta, not stuffed or otherwise prepared” (CPC 2731): 14 EPDs were selected, of which 13 related to semolina and 1 to wholemeal semolina;
3. Italian EPDs referring to “grain mill products” (CPC 2311). Five EPDs were selected: 1 for semolina; 2 for 00 and 0 type flour; 2 for wholemeal flour.

The data collected in the company were supplemented with data from EPDs.

## Materials and Methods

Note that EPDs for pasta production express data associated with the production of 1 kg of dry pasta. It was necessary to research data on the yield of the pasta production process. In Notarnicola et al. (2004) and Lo Giudice et al. (2011), 1.06 kg of semolina (94.34 % yield) is required to produce 1 kg of pasta. For pasta production, according to the most common recipes, 1.1 kg of semolina produces 0.95 kg of pasta (86.36%). In Notarnicola et al. (2000), 1 kg of couscous (90.25%) is obtained from 1.108 kg of semolina. The average of the yields (90.3%) was used to correct the data of the indicated EPDs so that the results refer to 1 kg of semolina.

### **Grain milling yield**

Table 1 shows the type of grain considered, the percentages of the different papers analysed, the average and the bibliographical sources. The milling of durum and soft wheat yields, as is well known, different products. The extraction percentage depends on the type of product to be obtained from the milling and subsequent sifting of the grain.

Table 1: bibliographic collection of the degree of sifting of durum and common wheat flours

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N. | Wheat | Sifting | Average | Source |
| 1 | Durum wheat | 75.57 % | 70.50 % | Bevilacqua et al. 2007 |
| 2 | 78.99 % | Ingaro et al. 2018 |
| 3 | 64.10 % | Lo Giudice et al. 2011 |
| 4 | 65.36 % | Notarnicola et al. 2001 |
| 5 | 66.25 % | Notarnicola et al. 2004 |
| 6 | 72.73 % | Seget et al. 2020 |
| 7 | Common wheat   | 67.62 % | 75.85 % | Camara-Salim et al. 2020 |
| 8 | 89.84 % | Chiarico et al. 2000 |
| 9 | 61.76 % | Comino et al. 2021 |
| 10 | 80.00 % | Kulak et al. 2015 |
| 11 | 80.00 % | Parenti et al. 2020 |

Different classes of flour as indicated in D.P.R n° 187/2001 (modified by D.P.R. n° 41/2013) were considered. Each of the associated products corresponds to a percentage of sifting. In particular, for soft wheat, there are five types of flour for which it was easy to associate the average extraction yield (Table 2).

For durum wheat, instead, semolina, semolate and wholemeal semolina were considered. Durum wheat flour is excluded because it constitutes a different product, with a non-granular structure, although the intermediate ash content among the others suggests that it is solely the result of a different yield from the same milling process. The degree of souring of durum wheat flour was determined by evaluating it together with the ash content, and these quantities were compared to understand the relationship between the two. The results show that it was possible to attribute a linear, albeit approximate, correspondence between the quantities considered (unlike soft wheat). In this way, it was possible to associate the relative degree of sifting to the three types of durum wheat flour: considering an average percentage of 68% (resulting from the average of the data from the publications on semolina) for semolina and assuming a yield of 100% for whole-wheat, it was possible to attribute an average degree of sifting of 84% to semolate.

Distinguishing the data collected from publications and EPDs, the results were averaged to associate a corresponding flour production. The average of the data collected from EPDs related to durum wheat was associated with the production of “semolina”. Knowing the yield of semolina and wholemeal semolina, the ratio used as a multiplier for the environmental profile of the durum wheat flours considered was calculated. For soft wheat, the average data were combined with the yield of “type 1 flour”. Noting the yield of type 1 flour and calculating the relationship with the other yields (00, 0, 2 and wholemeal), the factors for each type of flour were determined.

Table 2 and Table 3 show the different classes of flour laid down in the regulations, supplemented by the multiplication factor. The fraction will be greater or less than “1” depending on whether the type of flour considered is more or less refined than that associated with the starting flour. Multiplication factors were used to estimate resource consumption data (energy, water), so that the datasets for the milling phase could be defined.

Table 2: properties relating to types of soft wheat flours

|  |  |  |  |
| --- | --- | --- | --- |
| Common wheat flour | Sifting | Max ash | Multiplicative factor |
| Flour type 00 | 50% | 0.55 | 1.6000 |
| FLour type 0 | 72% | 0.65 | 1.1111 |
| Flour type 1 | 80% | 0.80 | 1.0000 |
| Flour type 2 | 85% | 0.95 | 0.9410 |
| Wholemeal flour | 100% | 1.70 | 0.8000 |

Table 3: properties relating to types of durum wheat flours

|  |  |  |  |
| --- | --- | --- | --- |
| Durum wheat flour | Sifting | Max ash | Multiplicative factor |
| Semolina | 68% | 0.90 | 1.0000 |
| Semolate | 84% | 1.35 | 0.8095 |
| Wholemole semolina | 100% | 1.80 | 0.6800 |

The co-products were quantified by mass balancing in the milling process and considering the weight percentages expressed in the cited publications. The co-products consist of bran and shorts, pollard, germ and screenings (other subproducts). The weight percentage of bran decreases as the sifting percentage increases and vice-versa. For durum wheat, the average percentage is 92.78% and the remainder consists of middlings, grains and rejects; for soft wheat, the average percentage is 98.10% and the difference indicates process rejects. Therefore, even wholegrain flour has a certain, albeit minimal, amount of by-products.

## Results and Discussion

A total of 16 wheat milling datasets were constructed: 8 estimated from publication data (3 for durum wheat and 5 for soft wheat) and 8 derived from data extracted from EPDs and supplemented with on-farm data (3 durum wheat and 5 soft wheat). The flours analysed are:

* durum wheat semolina;
* durum wheat semolina;
* durum wheat wholemeal flour;
* common wheat flour type 00;
* common wheat flour type 0;
* common wheat flour type 1;
* common wheat flour type 2;
* common wheat wholemole flour.

Table 4 shows, for illustrative purposes (and in compact form), the durum wheat semolina dataset resulting from the collection of data from EPDs integrated with company data.

Table 4: data-sets derived from EPD data collection supplemented with field data on the production of 1 kg of durum wheat semolina

|  |  |
| --- | --- |
|  |  |
| **Process information** |  |
| Process name | Durum wheat semolina production, national average |
| Geography | The data on durum wheat semolina production represent the production of flour in the main Italian mills, which account for 90% of national production. |
| Technology | The reference technology, with regard to energy consumption, considers both the renewable primary resource and the non-renewable primary resource installed in plants |
| Time period | The milling process data is for 2020 |
| Source  | National average, based on statistical data and on-field data |
| Literature references | EPD “uncooked pasta, not stuffed or otherwise prepared” (CPC 2731); EPD “grain mill products” (CPC 2311) |
| Allocation rules | In the joint production of semolina and co-products, data were not allocated. For possible allocation, the factors 0.89; 0.089; 0.01; 0.011 (for semolina, bran, pollard, germ, respectively) should be used. |
| Data tratment | The dataset is the result of combining literature data collected by EPDs and data collected directly in the mills that collaborated with the ILCIDAF project. |
| Completeness check | All relevant flows quantified |
| **Inventory data** |  |
| **PRDUCT/FUNCTIONAL UNIT** | **Name** | **Amount** | **Unit** |
| Functional unit | Quantity | 1 | Kg |
| Product | Semolina |  |  |
| **INPUT FLOWS** |  |  |  |
| **Type** | **Name** | **Amount** | **Unit** |
| Resources from the environmental | Durum wheat | 1,47E+00 | Kg |
| Energy input | Renewable primary energy resources (as energy carrier) | 8,31E-02 | kWh |
|  | Renewable primary energy resources (as a resource) | 5,60E-04 | kWh |
|  | Non-renewable primary energy resources (as energy carrier) | 2,02E-01 | kWh |
|  | Non-renewable primary energy resources (as a resource) | 2,91E-02 | kWh |
| Water input | Use of water resources | 1,85E+00 | L |
| **OUTPUT FLOWS** |  |
| **Type** | **Name** | **Amount** | **Unit** |
| Product | Semolina | 1,00E+00 | Kg |
| Co-product | Bran | 3,64E-01 | Kg |
|  | Pollard | 4,09E-02 | Kg |
|  | Germ | 4,09E-02 | Kg |
|  | Screenings | 2,44E-02 | Kg |
| Waste to treatment | Hazardous wastes | 1,13E-06 | kg |
|  | Non-hazardous wastes | 5,70E-02 | Kg |
|  | Radioactive waste | 2,59E-05 | Kg |
| **Administrative information** |  |
| Commissioner of data set | MUR – PRIN 2017 |
| Data entry by | University of Bari, Aldo Moro |
| Quality check by | University of Bari, Aldo Moro |
| Pubblication and ownership | Free of change for all users and uses |

Applying the described methodology to the collected data, it is possible to produce datasets wheat milling datasets for the different flour classes considered. Furthermore, they were estimated from different sources, i.e. scientific articles and EPDs relating to “uncooked pasta, not stuffed or otherwise prepared” (CPC 2731) and EPDs relating to “grain mill products” (CPC 2311) and integrated with data collected in the factory.

## Conclusion and future prospects

The data calculated and included in the datasets produced, independent of the source selected, are comparable with each other and consistent in terms of energy consumption, water consumption and mass balance. The data are not given in disaggregated form, i.e. for each stage of the milling process (cleaning, storage, conditioning, grinding and sieving), but in aggregate form. The data described refer to the Italian territory and in the case of EPDs the average technology installed in mills is also considered. The ILCIDAF project's special feature of characterising both soft and durum wheat flour constitutes an added value to the database made freely available online. Other commercial databases offer data on generic flour and its by-products. Only Agribalyse describes some flour classes, but only for soft wheat. A future implementation of these datasets could include the disaggregation of data on the sub-processes of the grain milling phase, but this is only feasible with a great effort and cooperation from the milling industry.

# Riferimenti

Bevilacqua M, Braglia M, Carmignani G, Zamori F A (2007). Life cycle assessment of pasta production in Italy. Journal of Food Quality, 30 (6), 932-952.

Camara-Salim I, Almeida-Garcia F, Gonzalez-Garcia S, Romero-Rodriguez A, Ruiz-Nogueiras B, Pereira-Lorenzo S, Moreira M T (2020). Life cycle assessment of autochthonous varieties of wheat and artisanal bread production in Galicia, Spain. Science of the Total Environment, 713, 136720.

Chiriaco M V, Grossi G, Castaldi S, Valentini R (2017). The contribution to climate change of the organic versus conventional wheat farming: A case study on the carbon footprint of wholemeal bread production in Italy. Journal of cleaner production, 153, 309-319.

Comino E, Dominici L, Perozzi D (2021). Do-it-yourself approach applied to the valorisation of a wheat milling industry's by-product for producing bio-based material. Journal of Cleaner Production, 318, 128267.

Ingrao C, Licciardello F, Pecorino B, Muratore G, Zerbo A, Messineo A (2018). Energy and environmental assessment of a traditional durum-wheat bread. Journal of Cleaner Production, 171, 1494-1509.

Kulak M, Nemecek T, Frossard E, Chable V, Gaillard G (2015). Life cycle assessment of bread from several alternative food networks in Europe. Journal of Cleaner Production, 90, 104-113.

Lo Guidice A L, Clasadonte M T, Matarazzo A (2011). LCI preliminary results in the Sicilian durum wheat pasta chain production. J. Commod. Sci. Technol. Qual, 50(1).

Nicoletti G M, Notarnicola B (2000). From home-made to industrial couscous: the process. Tecnica Molitoria, 51(12), 1253-1262.

Notarnicola B, Nicoletti G M (2001). Life cycle assessment of pasta and couscous. Tecnica Molitoria (Italy).

Notarnicola B, Nicoletti G M, Tassielli G, Mongelli I (2004). Environmental input-output analysis and hybrid approaches to improve the set-up of the pasta life cycle inventory. Jounrnal of Commodity Science, 1000-1028.

Notarnicola B, Tassielli G, Renzulli P A, Di Capua R, Saija G, Salomone R, Primerano P, Petti L, Raggi A, Casolani N, Strano A, Mistretta M (2022). Life cycle inventory data for the italian agri-food sector: background, sources and methodological aspects. The International Journal of Life Cycle Assessment, 1-16.

Parenti O, Guerrini L, Zanoni B (2020). Techniques and technologies for the breadmaking process with unrefined wheat flours. Trends in Food Science & Technology, 99, 152-166.

Seget S, Costa M, Barilli E, de Vasconcelos M W, Santos C S, Styles D, Williams M (2020). Substituting wheat with chickpea flour in pasta production delivers more nutrition at a lower environmental cost. Sustainable Production and Consumption, 24, 26-38.