



Review

Occurrence of environmental pollutants in foodstuffs: A review of organic vs. conventional food

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In recent years, there is an increasing trend to consume organic foods instead of the conventional foodstuffs. This tendency is mainly due to the concern raised by the potential adverse health effects derived from the intake of pesticides, fertilizers, hormones and antibiotics, which are widely used in regular food production. Although organic label forbids the use of these products, environmental contamination is likely to occur in both, conventional and organic foodstuffs. The main purpose of this review was to compare the levels of a number of environmental pollutants such as polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), mycotoxins, trace elements, polycyclic aromatic hydrocarbons (PAHs), etc., in organic and conventional food items. The results show that, in general, the presence of nearby anthropogenic sources of pollution is the key issue influencing the occurrence of environmental pollutants in foodstuffs, regardless their organic or conventional origin. Based on this, we suggest that environmental contaminants should be monitored in both conventional and organic foods. Finally, the safety feature, which has been globally attributed to organic foods, might be questionable depending on the potential environmental contamination of these foods.

1. Introduction

The consumption of organic foods has notably increased in recent years. In 2016, on a global level, up to 178 countries practiced organic agriculture, on an extension of 57.8 million hectares, with a market size of 89.7 billion US dollars. Hence, organic agriculture has considerably increased from 200,000 producers in 1999 to 2.7 million producers in 2016, being this tendency still forecasted (IFOAM, 2018).

Consumers' preference for organic foods is mainly associated with reasons related to personal health, animal welfare and environmental protection (Kesse-Guyot et al., 2018). However, health-related issues seem to be the most important reasons (Mie et al., 2017; Petrescu and Petrescu-Mag, 2015). Recent human epidemiological studies associated consumption of organic foods with lower risks of allergies, while results on human intervention studies are still ambiguous (Huber et al., 2011). The evidence is not conclusive because the consumers who decide to purchase organic food, might also exhibit specific socio-demographic characteristics, lifestyles, as well as food patterns of consumption (Kesse-Guyot et al., 2018; Simões-Wüst et al., 2017). In fact, studies focusing on the differences in nutritional values between organic and conventional food, have reported contradictory results (Galvano et al., 2016; Mazzoncini et al., 2015).

Organic food label entails no residue of synthetic fertilizers, chemical pesticides, genetically modified organisms (GMOs), hormones and antibiotics. However, there is ambiguity about the exact long-term large-scale impact of systems utilizing organic methods, GMOs, and conventional farming methods (Wunderlich et al., 2017). The European Food Safety Authority (EFSA) reported that the most detected residues (copper, and sponosad, a natural toxin, and bromide ion) in organic food are of low concern (EFSA, 2016). However, both, conventional and organic foods, may contain banned persistent (and toxic) pesticides, such as hexachlorobenzene, dichlorodiphenyltrichloroethane (DDT), lindane and dieldrin among others (Gomiero, 2018). For example, the consumption of an organic diet for one week, significantly reduces organophosphate pesticide exposure in adults (Oates et al., 2014). Furthermore, conventional and organic foods are equally exposed to environmental contaminants (Debnath et al., 2015; González et al., 2011). Therefore, organic foods could contain the same, or even higher content, of various environmental pollutants such as polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and heavy metals, than conventional food. The dietary intake of these compounds have been widely investigated in our lab (Domingo et al., 1999, 2003, 2012a,b; Domingo and Nadal, 2015; González et al.,

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Table 1
Summary of recent studies on the occurrence of environmental pollutants in organic and conventional foods.

Contaminant	Foodstuff	Remarks	Reference
DL-PCBs	Bovine meat	Meat from organic origin is more contaminated, after production stage and after cooking. Cooking reduces contamination levels	Tressou et al. (2017)
PAHs, PCBs and OCPs	Bovine, poultry and lamb meat	Differences between organic and conventional meats were minimal. Consumption of organic meat does not diminish the carcinogenic risk	Rodríguez-Hernández et al. (2017)
Trace elements (Cu, Zn, As, Cd, Pb and Hg)	French porcine meat	All the concentrations were below the regulatory limits. In muscles, Cu, Zn and As were detected at slightly higher levels in organic samples. Livers from conventional and Label Rouge pig farms exhibited higher Zn and Cd contents than the organic ones	Parinet et al. (2018)
PCDD/Fs, PCBs, HBCDs, mycotoxins and inorganic compounds (Zn, Cu, Pb, Hg, As and Cd)	Bovine, porcine and poultry meat	All the concentrations were below the regulatory limits. PCDDs, PCBs, HBCD, Zn, Cu, Cd, Pb and As levels were significantly higher in organic samples	Dervilly-Pinel et al. (2017)
PCBs, PAHs, pesticides and trace metals (Pb, Cd, As, Hg, Fe, Cu)	Cold-pressed rapeseed oil samples	Levels of PAHs, PCBs, and pesticides were within EU legislation limits. No correlation was found between organic and conventional cultivation method	Wroniak and Rekas (2017)
Mycotoxins, nitrates, pesticides, heavy metals	Wheat, lettuce and carrots	Organic head lettuce showed lower nitrate levels than those found in conventional products. Organically produced carrots contained higher nitrate levels than conventional products. Both organic and conventional products contained no residues of non-polar pesticides above the legal limits	Hoogenboom et al. (2008)
Antioxidants, Fe, Mg, P, nitrates	Fruits, vegetables and grains	Organic crops contained less nitrates than conventional crops. In general, organic products showed better quality and a higher content of nutritionally significant minerals with lower amounts of some heavy metals	Worthington (2001)
Pesticides	Fruits and vegetables	Organic foods contained about one-third of many residues than conventionally grown foods	Baker et al. (2002)
Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn	Vegetables	Results showed that conventionally grown vegetables tended to contain higher concentrations of some elements	Głodowska and Krawczyk (2017)
Micronutrients and heavy metals (Fe, Mg, Mn, K, Ca, Na, Zn, Cu, Ni and Cd)	Vegetables	Significant decrease in micronutrients in the edible part of crops from organic farming. However, toxic metals loads significantly increased in crops from conventional agriculture.	Hattab et al. (2019)
Heavy metals (Pb, Cd, Zn, Ni and Cr)	Carrots	The legal values were not exceeded in any case. Carrots produced by means of organic method contained significantly lower quantities of Pb, Cd and Zn than conventionally grown carrots	Gawęda et al. (2012)
Nitrate, heavy metals (Cd, Pb) and pesticides	Carrot, tomato, lettuce, spinach and potatoes	Consumers of organic products showed a higher intake of a selected set of nutrients and contaminants, which is explained by the general higher vegetable consumption of this consumer group	Hoefkens et al. (2010)
OCPs, OPPs and heavy metals (Zn, Cu, Mn, Fe, Cd, Pb, Cr, Ni and Co)	Potatoes	Contamination of pesticides and heavy metals was twice higher in conventionally grown potatoes. Residues of pesticides were above MRLs. Additionally, heavy metals were detected in most samples. Moreover, some of them exceeded de ML for Pb and Fe	Mansour et al. (2009)
Trace elements (Cu, Mn, Fe, Na, Ca, K and Zn)	Potatoes	Organic potatoes had significantly higher levels of Cu and Mn, significantly lower levels of Fe and Na, and similar levels of Ca, K and Zn than conventional potatoes	Griffiths et al. (2012)
Elemental (Na, K, Ca, S, P, Mg, Al, B, Fe, Zn, Mn, As, Cd, Cr, Cu, Ni and Pb) and nitrate content	Carrots	There are no differences between conventionally- and organically-grown carrots, as well as no potential harm arising from heavy metal contamination.	Krejčová et al. (2016)
PCDD/Fs and PCBs	Milk	Highest levels found in one organic and one conventional farm. Results suggested the environmental quality in extensive farming system should be eligible as a food safety factor, also for organic productions	Brambilla et al. (2011)
PCBs and OCPs	Milk	Low concentrations of OCPs, with lower levels in organic milk. Low concentrations of PCBs were also found, being those of the conventional milk lower than those of the organic milk.	Luzardo et al. (2012)
PCBs and OCPs	Cheese	The concentration of OCPs was low for both types of cheese, although organic products had lower concentrations than conventional ones. The levels of PCBs in cheese were also low; however, there were higher levels of PCBs in organic samples than in conventional brands	Almeida-González et al. (2012)
45 trace elements and 6 major elements	Milk	Organically produced milk contained higher levels of Mo, but lower levels of Ba, Eu, Mn and Zn.	Hermansen et al. (2005)
Co, Cr, Cu, Fe, I, Mn, Mo, Ni, Se, Zn, As, Cd, Hg and Pb	Milk	Essential trace element concentrations in organic milk were significantly lower compared to conventional milk. Toxic metal concentrations in milk were in general very low. No significant differences were observed between samples of organic and conventional milk	Rey-Crespo et al. (2013)
Ochratoxin A	Cereals (baby food)	Ochratoxin A was detected in 20 out of 119 batches, and particularly four of these showed ochratoxin A above the Italian legal limit (0.5 µg/kg)	Beretta et al. (2002)
Ochratoxin A	Flours and bakery products	Ochratoxin A levels in flour and flour derivatives were below the legal limit. In baby food, 4 samples exceeded this value. No relevant differences were found between the two types of agricultural practice when all types of cereal derivatives were considered together	Biffi et al. (2004)
Mycotoxins, heavy metals and pesticides	Flour, bread, breakfast cereals, dough and pastry	Mycotoxins and Hg concentrations were higher in conventional than in organic foodstuffs, while Cd and Pb occurred at higher concentrations in organic than in conventional food samples.	Harcz et al. (2007)
Mycotoxins	Cereals and cereal-based products	The type of production did not affect the mycotoxin levels, as no significant differences were found between organic and conventional	Pleadin et al. (2017)

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Table 1 (continued)

Contaminant	Foodstuff	Remarks	Reference
Pb and Cd	Infant cereals	products. Consumption of these foodstuffs does not mean a risk for human health Higher content of lead and cadmium in organic cereals in comparison with conventional ones	Hernández-Martínez et al. (2012)
Pb, Cd, Cu, Zn and Fe	Wheat, green lentils, flower honey and eggs	Cd and Pb levels were below the LOD, whereas Cu levels were below LOD only in flower honey samples. Levels of Zn and Cu were found to be higher in conventionally produced wheat samples than in organically produced ones. The level of Fe in organic products was found to be higher than that in the conventional products	Arslanbaş and Baydan (2013)
OCPs, PCBs, Pb, Cd and mycotoxins	Milk and meat	In both, organic and conventional milk, and meat, concentrations of pesticides and PCBs were lower than the legal limits. Pb and Cd concentrations were very low and did not differ between organic and conventional products. Aflatoxin M1 in some organic milk samples was significantly higher than those of conventional milk	Ghidini et al. (2005)
PCBs and PCDD/Fs	Eggs	Concentrations of PCBs and PCDD/Fs in organic eggs were lower than the levels in conventional eggs. Only 3% of the samples exceeded the EC limit for PCDD/Fs (2.5 pg OMS-TEQ/g). For PCBs, all sampled were below the EC safety level (40 ng/g).	Rawn et al. (2012)

2018; Llobet et al., 2003, 2008; Martí-Cid et al., 2008a, 2008b, 2009, 2010; Martorell et al., 2012; Perelló et al., 2012, 2014, 2015a, 2015b).

Based on the above, the present review-article was aimed at reviewing recent studies in which the levels of a number of environmental pollutants are compared in both conventional and organic foodstuffs. The manuscript is mainly focused on those compounds not considered in organic food regulation. Hence, we have discarded studies aimed at: a) reporting levels of fertilizers and/or pesticides in conventional and/or organic food, and b) providing concentrations of environmental pollutants in food, regardless its agriculture/farming system.

2. Food and contaminants

PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/>) and Scopus (<https://www.scopus.com>) were used as databases using the following search terms: “environmental contaminants”, “environmental pollutants”, “organic food” and “conventional food”. Table 1 summarizes up to 28 studies comparing the occurrence of environmental contaminants in organic and conventional meat, oil, vegetables and fruits, milk and dairy products, and other foodstuffs (eggs, honey and lentils) on which information could be found. Next, we discuss some results.

2.1. Meat

In recent years, a number of studies have compared the presence of environmental contaminants in organic versus conventional meat. Tressou et al. (2017) determined the concentration of dioxin-like PCBs (DL-PCBs) in bovine meat, using three different cooking intensities (rare, medium and well-done). It was found that organic bovine meat was more contaminated than the conventional one, with cooking reducing the contamination levels. Similar results were also reported by Dervilly-Pinel et al. (2017) who also determined the levels of PCBs along with PCDD/Fs, hexabromocyclododecanes (HBCDs), mycotoxins and inorganic compounds in bovine, porcine and poultry meat. The findings revealed that the levels of contamination were below the regulatory limits in all samples. However, PCBs were significantly higher in organic meat samples, while the concentrations of PCDD/Fs, HBCDs, Zn, Cu, Pb, Cd and As were also higher in organic samples.

In turn, Rodríguez Hernández et al. (2017) determined the concentrations of some POPs (7 PAHs, 18 PCBs and 8 organochlorine pesticides (OCPs)) with known carcinogenic potential, in three different types of meat (beef, chicken and lamb). Differences between organic and conventional meat were minimal, and the consumption of organic meat did not reduce the carcinogenic risk. Likewise, Parinet et al.

(2018) measured the levels of several trace elements (Cu, Zn, As, Cd, Pb and Hg) in French pig meat. None of the samples were over the regulatory limits. In samples of muscle, some elements (Zn, As and Cu) were slightly higher in organic than in conventional samples. In contrast, livers from conventional meat showed higher levels than those found in the organic samples.

2.2. Oils

Information comparing organic and conventional oils is very scarce. In fact, in the scientific literature, only one paper is available. Wroniak and Rękas (2017) determined the levels of PCBs, PAHs, pesticides and various trace metals (Pb, Cd, As, Hg, Fe, Cu) in cold-pressed rapeseed oil samples. All samples were found to be below the regulatory limits. Four PAHs had levels oscillating between 3.13 and 615 µg/kg; the concentrations of non-dioxin-like PCBs (NDL-PCBs) varied between 2599.4 and 8380.8 pg/g, while Fe and Cu were the prevailing heavy metals, with values of 0.236–1.690 mg/kg and 0.036–0.062 mg/kg, respectively. Moreover, a correlation between organic and conventional cultivation method was not found.

2.3. Vegetables and fruits

Various authors have paid attention to the comparison between organically and conventionally grown vegetables and fruits. Most studies focused on the intake of nitrates, heavy metals and pesticides. In general terms, organically grown vegetables showed significant less amounts of nitrates when compared to conventional crops (Hoogenboom et al., 2008; Worthington, 2001). Conventional crops tended to have more contaminants, like heavy metals and pesticides, than organic crops (Baker et al., 2002; Głodowska and Krawczyk, 2017; Hattab et al., 2019; Worthington, 2001; Gawęda et al., 2012).

In contrast, other authors did not find differences between organic and conventional vegetables. Furthermore, they stated that there was no sufficient evidence to recommend organic crops over conventionally grown vegetables (Hoefkens et al., 2010; Krejčová et al., 2016).

Mansour et al. (2009) evaluated the content of organochlorine pesticides and heavy metals in conventional and organic potatoes. Results revealed a contamination of conventional potatoes nearly 2 times higher than that of organic potatoes, by either pesticides or heavy metals. Few years later, Griffiths et al. (2012) also reported levels of trace elements in potatoes. Findings showed that organic potatoes had higher levels of Cu and Mn, lower levels of Fe and Na, and similar levels of Ca, K and Zn than those found in conventionally grown potatoes.

On the other hand, some authors measured contaminant levels only in organic samples. In three different crops, levels of PAHs, PCBs and OCPs were between 8.42 and 40.1 µg/kg, 0.83 and 2.68 µg/kg, and 8.09 and 133 µg/kg, respectively (Zohair et al., 2006). In another recent study, pesticides were measured in organically grown carrots. Bendiocarb was detected above the limit (199.11 µg/kg), while other pesticides (chlorpyrifos and amitraz) were also detected (43.20 µg/kg and 11.22 µg/kg, respectively). Therefore, assessment of environmental pollutants should be conducted in order to ensure consumers that organic food is free of contamination, as expected (Chiarello and Moura, 2018).

2.4. Milk and dairy products

During the last and the current decades, some studies have assessed the levels of some organic compounds, such as pesticides, PCDD/Fs and PCBs, in milk and dairy products.

Brambilla et al. (2011) determined the occurrence of PCDD/Fs and DL-PCBs in sheep milk, remarking that the highest cumulative level (2.1 pg WHO-TEQ/g fat) was found in one organic and one conventional farm close to an important bushfire. In turn, Luzardo et al. (2012) and Almeida-González et al. (2012) evaluated the concentrations of PCBs and OCPs in conventional and organic brands of milk and cheese, respectively. The results of both studies agreed with the fact that OCPs and PCBs concentrations were low in both types of milk and cheese. However, OCPs were lower in organic samples than in those of conventional farms, while PCBs were higher in organic than in conventional samples. In addition, these authors remarked that numerous brands of milk were highly contaminated with PCDD/Fs and DL-PCBs, regardless of the type of farming, indicating that people consuming the most contaminated brands, could exceed the recommended TDI (2 pg WHO-TEQ/kg bw/day) (SCF, 2001).

In parallel, two studies were aimed at monitoring inorganic compounds in milk and dairy products. Hermansen et al. (2005) reported the occurrence of major and trace elements in organic and conventional milk samples collected in Danish dairy farms. It was highlighted that organically produced milk, in comparison with conventionally produced milk, contained a significant higher concentration of Mo (48 vs. 37 ng/g) and a lower concentration of Ba (43 vs. 62 ng/g), Eu (4 vs. 7 ng/g), Mn (16 vs. 20 ng/g) and Zn (4400 vs. 5150 ng/g). In turn, Rey-Crespo et al. (2013) measured the levels of trace (essential, but also toxic) elements in organic and conventional milk in NW Spain. As expected, essential trace element concentrations in conventional milk were significantly higher than those found in organic milk, mainly due to the supplemented feed. On the other hand, toxic metal concentrations in milk were very low, and without significant differences between the two types of farming.

2.5. Cereals

The occurrence of mycotoxins in cereals, considering different agriculture practices, is also an issue of interest. Beretta et al. (2002) reported that ochratoxin A was undetectable -or below the limit of detection (LOD)- in most cereal-based baby foods. However, ochratoxin A was detected in 20 out of 119 batches. Particularly, four of these showed ochratoxin A above the Italian legal limit (0.5 µg/kg). Only samples from integrated pest management system were below the LOD, while up to 5% of batches from conventional and organic agriculture were above the permitted value. On the other hand, Biffi et al. (2004) reported that commercial flours and derivatives (211 Italian flours and bakery products) contained ochratoxin A at concentrations much lower than the legal limit, being many of them below the LOD. Similarly to the results of Beretta et al. (2002), four samples of baby food were above the Italian legal limit. However, no significant differences were found between conventional and organic agriculture when the types of cereal derivatives were considered all together. Similarly, Pleadin et al.

(2017) concluded that the type of production did not affect mycotoxin contamination, because no significant differences were found between the two production methods. By contrast, Remza et al. (2016) found lower contamination by *Fusarium* toxins (deoxynivalenol, nivalenol and zearalenone) in wheat and rye from organic farming than in conventional samples.

Harcz et al. (2007) conducted a study aimed at compiling a database with the levels of various contaminants (mycotoxins, heavy metals and pesticides) monitored from 2002 to 2005 in samples of winter wheat, which were obtained in Belgium from organic and conventional agriculture systems. It was found that mycotoxins and Hg concentrations were higher in conventional than in organic foodstuffs (deoxynivalenol: 0.56 vs. 0.99 µg/kg bw; zearalenone: 0.03 vs. 0.06 µg/kg bw; Hg: 0.0006 vs. 0.0007 µg/kg bw), while Cd and Pb occurred at higher concentrations in organic samples than in conventional food (Cd: 0.19 vs. 0.17 µg/kg bw; Pb: 0.28 vs. 0.12 µg/kg bw). Finally, it was noticed that consumers of conventional products also ingested some post-harvest insecticides, which should be also considered (chlorpyrifos-methyl: 0.11 µg/kg bw; dichlorvos: 0.2 µg/kg bw; pirimiphos-methyl: 0.24 µg/kg bw). Conversely, Hernández-Martínez and Navarro-Blasco (2012) reported a higher content of Pb and Cd in organic cereals than in samples of conventional cereals (Pb: 26.07 vs. 10.78 µg/kg; Cd: 18.52 vs. 7.12 µg/kg) collected in Spain. However, only 3 formulations were above the European lead maximum level. Furthermore, a potential role of added ingredients (milk, cocoa, fruit and honey) was also noticed. Organic infant cereals, namely enriched with honey and cocoa, showed the highest risk intake of Pb and Cd, respectively.

2.6. Miscellaneous

This section reviews studies aimed at assessing the concentrations of environmental pollutants in none or more than one food groups discussed in the previous specific sections.

Labrinea et al. (2011) analyzed the content of ochratoxin A in wines from various viticulture and enological practices across Greece. Results showed a high frequency of ochratoxin A in commercially available wines (69% of positive samples). Notwithstanding, it was concluded that the level of contamination was low, with no significant differences based on wine color, production years, or cropping systems.

Arslanbaş and Baydan (2013) determined the levels of metals (Pb, Cd, Zn, Fe and Cu) in wheat, green lentils, honey and eggs from organic and conventional origin. It was found that Cd and Pb were below the respective LODs, while Cu was below the LOD only in honey and eggs. Conventional wheat samples showed higher concentrations of Zn and Cd than those of organic wheat. On the other hand, Fe levels were higher in organic products than in conventional ones. In turn, Rawn et al. (2012) assessed the impact of production type (conventional, omega-3 enriched, free range, organic and free run) on the occurrence of PCBs and PCDD/Fs in Canadian chicken egg yolks. It was found that the method of raising chickens had no impact on the pollutants levels. This finding contrast to that found in Europe, where free range eggs had higher concentrations of environmental pollutants than the eggs from conventionally grown chickens (Van Overmeire et al., 2009, 2006).

On the other hand, Ghidini et al. (2005) assessed the occurrence of OCPs, PCBs, lead, cadmium and mycotoxins in both, organic and conventional milk and meat. Pesticides and PCBs residues in the samples of milk and meat were lower than the legal limits, while lead and cadmium levels were low, and very similar. Although some samples of organic milk showed significantly higher aflatoxin M1 contamination than those of conventional milk, it was concluded that other factors than organic production might also have a potential role.

3. Conclusions

In the current review-article, the occurrence of various environmental contaminants (i.e.: PCDD/Fs, PCBs, PAHs, trace elements) have

been reviewed in both organic and conventional foods. There is a considerable amount of studies monitoring the concentrations of environmental pollutants in regular foodstuffs, while many others report pesticides concentrations in foodstuffs, with and without organic label. However, to date few efforts have been invested on the comparison of pollutants levels in organic and conventional foodstuffs.

Meat, vegetables and fruits, milk and dairy products, and cereals were found to be among the foodstuffs of main interest, while oil has been less studied. Due to the nature of environmental contaminants and foods, organic and inorganic pollutants are usually monitored in meat (muscle, fat, liver), vegetables and fruits. On the other hand, milk and dairy products are also good monitors of organic contamination. Finally, mycotoxins are contaminants of concern in cereals. In general terms, organic and conventional agriculture/farming was not found to be a key parameter regarding the occurrence of environmental pollutants. In fact, there are more studies reporting higher levels of environmental pollutants in organic foods than in conventional ones. The proximity to anthropogenic sources of contamination, such as traffic, bushfires, chemical industries, etc. should have a crucial role on the occurrence of environmental pollutants in foodstuffs.

One of the most relevant conclusions of this paper is that consuming organic food should not be necessarily considered healthier than consuming conventional foods. Organic label literally means that pesticides, synthetic fertilizers, hormones and antibiotics must not be used along the agriculture/farming system. However, organic food certification does not mean that foodstuffs are free of environmental contaminants.

Transparency document

Transparency document related to this article can be found online at <https://doi.org/10.1016/j.fct.2019.01.021>.

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