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Climate Change and Infant Nutrition: Estimates of Greenhouse Gas Emissions From Milk Formula Sold in Selected Asia Pacific Countries

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Abstract

Background: There is growing recognition that current food systems and policies are environmentally unsustainable. There is an identified need to integrate sustainability objectives into national food policy and dietary recommendations.
Research Aims: To (1) describe exploratory estimates of greenhouse gas emission factors for all infant and young child milk formula products and (2) estimate national greenhouse gas emission association with commercial milk formulas sold in selected countries in the Asia Pacific region.
Method: We used a secondary data analysis descriptive design incorporating a Life Cycle Assessment (LCA) concepts and methodology to estimate kg CO_2 eq. emissions per kg of milk formula, using greenhouse gas emission factors for milk powder, vegetable oils, and sugars identified from a literature review. Proportions of ingredients were calculated using FAO *Codex Alimentarius* guidance on milk formula products. Estimates were calculated for production and processing of individual ingredients from cradle to factory gate. Annual retail sales data for 2012–2017 was sourced from *Euromonitor International* for six purposively selected countries; Australia, South Korea, China, Malaysia, India, Philippines.
Results: Annual emissions for milk formula products ranged from 3.95–4.04 kg CO_2 eq. Milk formula sold in the six countries in 2012 contributed 2,893,030 tons CO_2 eq. to global greenhouse gas emissions. Aggregate emissions were highest for products (e.g., toddler formula), which dominated sales growth. Projected 2017 emissions for milk formula retailed in China alone were 4,219,052 tons CO_2 eq.
Conclusions: Policies, programs and investments to shift infant and young child diets towards less manufactured milk formula and more breastfeeding are "Triple Duty Actions" that help improve dietary quality and population health and improve the sustainability of the global food system.

Keywords

Asia, climate change, environmental analysis, environmental change, formula feeding, Global Strategy for Infant and Young Child Feeding, infant formula, nutrition policy, Australia, carbon footprint, green-house gas, breast milk substitutes

Background

Globalization is reshaping food systems towards energy-dense diets, particularly in Asia (Baker & Friel, 2014, 2016). There also is growing recognition in the past decade that as well as contributing to rising obesity and chronic disease (Popkin, 2001a, 2001b), current food systems and policies are environmentally unsustainable (Food and Agricultural Organization, 2010b; Lawrence et al., 2015; McMichael et al., 2007). There is an identified need to integrate sustainability objectives into national food policy and dietary recommendations (FAQ, 2010b; Food and Agriculture

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Organization, 2016). Since 2016 the FAO has recommended that climate change impact needs to be considered when developing dietary guidelines and policies. FAO defines "sustainable diets" as those that have low environmental impacts and are i) nutritionally adequate, ii) affordable, and iii) culturally acceptable. Reducing production and consumption of animal-based foods in the Asia Pacific region is a key strategy for reducing greenhouse gas emissions and improving dietary health (McMichael et al., 2007). Changes throughout food systems to reduce environmental impact also can improve population health (Friel et al., 2009; Scarborough et al., 2012).

It is complex to accurately measure the carbon footprint of food, but livestock-based products have larger carbon footprints (Röös et al., 2014). The dairy industry is a key source of greenhouse gas emissions, globally (FAQ, 2010a). Greenhouse gas resulting from dairy in adult dietary patterns has been examined by several researchers (Auestad et al., 2015; Heller & Keoleian, 2015). However, whether current trends in milk formula use are relevant to food system sustainability is not known (Willett et al., 2019).

Recently researchers using *Euromonitor International* data for the food industry have shown that global sales of commercial milk formula (MF) products targeting infants and young children (IYC) are boomingBaker, Smith, et al., 2016. This has been characterized as a historically significant "infant nutrition transition" (Baker, Smith, et al., 2016), driven by a range of social and political factors (Baker et al., 2020). More than two-thirds of infants are now exposed to human milk substitutes during the first 6 months of life (Rollins et al., 2016). This is despite World Health Organization (WHO)/United Nations Children's Fund (UNICEF) global recommendations for exclusive breastfeeding for 6 months and continued breastfeeding to 2 years and beyond (WHO/World Health Organization, & United Nations Children's Fund, 2003).

The trend is led by rapidly developing, middle-income countries in the Asia Pacific region. In China, exclusive breastfeeding of infants aged 0–6 months drastically declined from 67% to 28% between 1998 and 2013 (Hou, 2014), and is now 20.8% (UNICEF, 2019). Fewer than one in 10 children in China continue breastfeeding at 2 years or beyond. However, diversity in the region exists; exclusive breastfeeding rates (0–5.99 months) in Korea are 11.4%, contrasting, for example, with India (54.9%; UNICEF, 2019). Even so, between 2008–2013 retail sales of MF products within the Asia Pacific region grew by 72.8%. Central to market growth is milk formula marketed for older infants and toddlers. The WHO (2018) has stated that these so-called "follow-up" and "growing up" milk products are unnecessary and potentially harmful to child nutrition and health, including through displacing continued breastfeeding.

Breastfeeding is the evolved optimal food system for human infants and young children (Sellen, 2001) and its premature displacement from children's diets has serious and wide-ranging adverse health results for both child and mother. As well as adding to obesity and chronic disease burdens, substantial mortality arises in all (high, middle, and lower income) country settings, from SIDS, necrotizing enterocolitis and infectious diseases, and maternal breast cancer. Associated economic costs (e.g., from lost lives, lower productivity, or higher health costs) are high (Rollins et al., 2016; Walters et al., 2019, 2016).

The rapid and widespread dietary shift towards human milk substitutes (i.e., any milks or products that could be used to replace milk, e.g., fortified soy milk, in either liquid or powdered form, that are marketed for feeding IYC up to 3 years of age, including follow-up formula and growing-up milks), raises questions about its environmental costs as well as water depletion and pollution, land clearing and biodiversity, waste disposal, and greenhouse gas emissions (Linnecar et al., 2014). Recently, researchers conducting a global study examined the carbon footprint of infant formula for children less than 6 months old (Karlsson et al., 2019), estimating a carbon footprint of 11–14 kg CO^2 eq. per kg of product. This covered the product life cycle but excluded MF products for older infants and young children, and produced no country-level estimates of emissions. Estimates for all IYC MF products have been compiled for North America (Cadwell et al., 2020). However, researchers have not addressed the impact on greenhouse gas due to the milk formula sales boom in Asia Pacific countries—where the global infant nutrition transition is focused (Baker et al., 2020; Baker, Smith, et al., 2016). We aimed to provide exploratory estimates of greenhouse gas emission factors for all IYC milk formula products and estimate national greenhouse gas emission impacts for MF sold in selected countries in the Asia Pacific region.

Key Messages

- Infant and young child diets, specifically milk formula products, are neglected in debates about food system sustainability.
- Milk formula greenhouse gas emissions in the selected Asia Pacific countries in 2012 exceeded 6.9 billion miles of car travel.
- Breastfeeding is the evolved food system for human infants and young children.
- Sustainable food policy and diets must include the protection, promotion, and support of breastfeeding.

Method

Design

We used a secondary data analysis descriptive design incorporating a Life Cycle Assessment (LCA) concepts and methodology. The LCA approach is most commonly used for evaluating the environmental effects of a particular activity,

service, or product (Flysjö, 2012), but also for other relevant sustainability and consumers aspects, including working conditions and animal welfare (Notarnicola et al., 2017).

Sample

Purposive sampling was used to select six countries from South Asia, East Asia, and the Pacific region to focus on countries that may be assumed to be particularly illuminating about the amount of greenhouse gas emissions by countries in this region. The countries selected (India, Philippines, China, Malaysia, Australia, and South Korea) illustrate greenhouse gas emissions for lower-middle, upper-middle, and high-income countries, and also countries with large and small populations, and with high or low breastfeeding rates. They therefore represent different sized potential markets and greenhouse gas emission levels. The sample also included both milk formula exporting and importing countries.

Measurement

The LCA facilitates comparison across different production systems and products by applying a standard approach, taking into account the environmental impacts during all life cycle stages of a product, including the extraction of raw materials, production, transportation, usage, and waste management (International Dairy Federation [IDF], (2015). During LCA analysis, the reference unit that denotes the useful output of the production system is known as the functional unit, and it has a defined quantity and quality. The functional unit used in this study was 1 kg of MF product, manufactured to meet international food standards for energy requirements of MF products. Our system boundary excluded the milk formula ingredient blending process (e.g., emissions from energy use) due to lack of data. It also excluded post manufacturing activities related to the packaging process, retail distribution, consumer use (for example, refrigeration and hygienic preparation), and waste disposal phases, making this a partial LCA analysis.

Data about retail sales of MF in study countries came from Euromonitor International *Baby Food* country reports (Euromonitor International, 2014). Euromonitor is a commercial database containing data collected from trade associations, industry bodies, business press, company financial reports, company filings, and official government statistics, and estimates are validated through industry consultation. Projections are calculated by Euromonitor through establishing a historic market trend and then factoring in possible future market changes (e.g., from birth rates or policy changes). A detailed description of the dataset is provided in the *Lancet Breastfeeding Series* study by Rollins et al. (2016). The Euromonitor data categorizes the four MF products targeting the IYC market as: special baby milk formula (SBMF); standard milk formula (SF); follow-on milk formula (FOF); and toddler milk formula (TF). The last two products are known together as follow-up formula (FUF) or growing up milks (GUMs), while the former are commonly referred to as infant formula (IF) (Baker, Smith, et al., 2016).

Data Collection

Data were extracted by the research team from country reports sourced from the *Euromonitor Passport Global Market Information* database for the years 2013–2015, which included Euromonitor projections to 2017.

Data Analysis

Retail sales of the above MF products in the selected countries was assumed, for simplicity, to be all locally produced and consumed, as the Euromonitor dataset does not distinguish sales of imported or exported MF products. Average emission factors were used to calculate the results of national greenhouse gas.

Greenhouse gas emissions from MF products was calculated as described below. MF comprises mainly milk powder (usually cow's milk) as a source of proteins; vegetable oil as a source of lipids; high fructose corn syrup or corn syrup, cane sugar, or lactose as a source of carbohydrates, and some micronutrients. These are manufactured into a final product using dry or wet blending industrial processes. The FAO Codex Alimentarius Commission (Codex) guides manufacturing standards, known as "the Food Code." A four-step process was used to account for the MF macronutrient composition required by Codex, and the major ingredients providing those macronutrients. Details are provided in the Supplemental Material and Tables.

First, the composition of MF was identified by reference to Codex manufacturing standards (Codex Alimentarius). MF products have different manufacturing standards and composition to reflect the different nutritional requirements of younger infants (0–6 months) compared to older infants and young children (7–36 months).

Second, the percentage contribution of each ingredient in the composition of MF was calculated conforming to Codex guidelines for carbohydrate, protein, and lipid content. This differs for SBMF and SF compared to FUF and TF so we calculated the contribution of ingredients for each of these two types of products.

Third, greenhouse gas emission factors due to individual ingredients of milk MF were identified from available literature. Emissions per kg of MF products were then calculated for different possible combinations of major ingredients, that is, carbohydrates (high fructose corn syrup, cane sugar, lactose, milk powder), proteins (milk powder, whey protein concentrate), and lipids (commonly used vegetable oils). This permitted estimation of an average emission for both the SF (including SBMF) and for the FUF (including TF), as

Table 1. Annual Greenhouse Gas Emissions (kg CO_2 eq.) from Retail Sales of MF Products in Six Asia Pacific Countries in 2012, Tons.

Variable	Australia	China	India	Malaysia	Philippines	South Korea	Total
MF - Total	31,742	2,249,287	111,227	218,149	204,304	78,321	2,893,030
SF/SBMF (0-6 months)	18,281	575,515	44,621	35,945	58,460	39,166	771,987
FUF (7-36 months)	13,461	1,673,772	66,606	182,204	145,844	39,155	2,121,042

Note. MF = formula milk; SF/SBMF = standard milk formula/special baby milk formula; FUF = follow-up or growing up milks.

our analysis aimed to calculate emissions for both types of MF products.

Fourth, annual emissions associated with MF sales for each individual country were estimated by multiplying the greenhouse gas emissions per kg of MF, by the volume of sales of MF products for the selected countries in 2012 and 2017 (projection), as our analysis aimed to estimate national greenhouse gas emission impacts for all MF products marketed in the selected countries.

Results

Greenhouse Gas Emissions per Kilogram of Milk Formula

The average greenhouse gas emission for MF products targeting infants 0–6 months was 3.95 kg CO_2 eq. per kg. For FUF products targeting young children aged 7–36 months, the average emission was 4.04 kg CO_2 eq. per kg of MF product. This is dry weight.

Aggregate Greenhouse Gas Emissions due to Milk Formula in the Six Study Countries

Multiplying retail sales volumes by the average greenhouse gas emission produced the greenhouse gas emission levels due to MF sold in an individual country. A total of 720,450 tons of MF products were sold in 2012 in the six study countries, contributing an estimated total of around 2.9 million tons CO_2 eq. to greenhouse gas emissions (Table 1).

Greenhouse gas emissions were highest in China, an upper middle-income country with a large population, which had annual emissions of around 2.2 million tons associated with MF retail sales. Around 1.7 million tons of these were for FUF products.

Sales were projected to grow by over 70% within the 5 years to 2017 (Table 2). Most rapid growth was anticipated for FUF products. For 2017, FUF product sales generated the largest greenhouse gas emission for the group of countries studied, at 3.8 billion tons CO_2 eq. (Table 3). This reflected large projected sales of TF in China, Malaysia, and Philippines. Greenhouse gas emissions from MF for infants (SF/SBMF) was an estimated 1.2 million tons CO_2 eq., while 3.7 million tons CO_2 eq. of greenhouse gas emissions were attributable to FUF sold in these six countries during 2017.

Of approximately 5 million tons CO_2 eq. arising from projected sales in the six countries during 2017, most was generated from products sold in China. Around three quarters was associated with FUF products. Projected emissions in India were much lower for MF sales, considerably lower than in China. India is a lower-middle income country with high breastfeeding rates. Emissions arising from MF sales in Malaysia and Philippines were twice as large as in India, despite their smaller populations, related to their lower breastfeeding rates. FUF product sales were the most important greenhouse gas emission sources in all countries except for Australia.

Discussion

We have illustrated the greenhouse gas implications of the ongoing infant nutrition transition in the Asia Pacific region, demonstrating the potential scale of emissions associated with MF use, particularly FUF. Emissions were estimated to be at least 3.95 kg CO_2 eq. per kg for infant formula

Table 2. Projected Percentage Increase in Annual Greenhouse Gas Emissions From MF Products, 2012–2017, for Six Asia Pacific Countries.

	2012		2017		2012-2017
Variables	Sale (tons)	Greenhouse Gas Emissions (kg CO_2 eq.)	Sale (tons)	Greenhouse Gas Emission (kg CO_2 eq.)	Projected Increase
MF - total	720,450	2,893,030	1,236,514	4,968,534	72%
SF/SBMF (0-6 months)	195,440	771,987	299,791	1,184,174	53%
FUF (7-36 months)	525,011	2,121,042	936,723	3,784,360	78%

Note. MF = formula milk; SF/SBMF = standard milk formula/special baby milk formula; FUF = follow-up or growing up milks.

Table 3. 2017 Forecasted Greenhouse Gas Emissions (kg CO_2 eq.) From MF Products Grouped by Country.

Variable	Australia	China	India	Malaysia	Philippines	S. Korea	Total
MF - total	34,365	4,219,052	122,771	295,941	223,983	72,423	4,968,534
SF/SBMF (0-6 months)	19,676	971,700	49,205	43,845	63,595	36,153	1,184,174
FUF (7-36 months)	14,689	3,247,352	73,566	252,096	160,388	36,269	3,784,360

Note. MF = formula milk; SF/SBMF = standard milk formula/special baby milk formula; FUF = follow-up or growing up milks.

products, and 4.04 kg CO_2 eq. per kg for "follow-up" and "growing up" milk. Using the U.S. Environmental Planning agency calculator, the aggregate emissions attributable to milk formula sold in the six countries in 2012 equates to emissions from about 6.9 billion miles driven in a car (U.S. Environmental Protection Agency [USEPA], 2015). By 2019, China alone was generating greenhouse gas emissions of this magnitude (Smith, 2019). FUF, especially TF formula sales in China, Malaysia, and the Philippines, was the largest source of emissions in most of the countries studied.

Our findings for these Asia-Pacific countries expand on results from other research in countries in Europe and North America, which has shown the comparative importance of greenhouse gas emissions from milk formula products (Cadwell et al., 2020; Joffe et al., 2019; Karlsson et al., 2019). Our results indicated a concerning high potential for interacting influences by large population size, declining breastfeeding rates, and rising affluence in countries of this region, on future trends in emissions. These emissions are substantially generated during the production phase in high income countries with small populations (Australia), but are driven by consumption levels in large, middle income countries with declining breastfeeding rates (e.g., China). Coupled with the findings about the consumption phase emissions from the Karlsson et al. (2019) study, these results are alarming. They reported that the consumption phase (i.e., the stages of the product life cycle after the product leaves the factory) accounted for up to a third of total greenhouse gas emissions of MF (mainly due to energy used for sterilizing feeding implements), and the importance of coal-fired cooking stoves in China resulted in a particularly high emission level from MF consumption in that country.

A key contribution of our study is to highlight the important role of FUF and TF to the global greenhouse gas impact of MF products, which is driven substantially by the sales boom in Asia (Baker et al., 2020). The study by Karlsson et al. (2019) excluded milk formula products marketed for older infants or young children, FUF, or TF.

Also, importantly, estimates for FUF and TF products emphasized that the overall carbon footprint of breastfeeding for older infants and young children is more favorable than for infant formula. This is because the nutritional demands on the mother from continued breastfeeding (6–36 months) are much lower than for the exclusive breastfeeding of infants (0–6 months). Exclusive breastfeeding has a lower carbon footprint than infant formula, especially in Asia where diets are typically more plant-based (Karlsson et al., 2019).

Our estimates of emissions per kg are lower than those reported by other researchers. Karlsson et al. (2019) found that the greenhouse gas emissions from producing one kg of packaged SF up to the factory gate varied between 7.1–11 kg CO_2eq. Cadwell et al. (2020) found values of around 8.49 kg CO2 eq. per kg of FUF and 9-10 kg CO2 eq. per kg of TF.

There is a need for a more detailed investigation of how MF sales data align with individual, country, and global level data on breastfeeding practices (Baker, Smith, et al., 2016). Our findings also point to the importance of further research to calculate greenhouse gas emissions for all countries in the Asia Pacific region and for other regions of the world, in order to provide aggregate estimates for whole regions and globally, and to allow comparison with other regions (WHO, 2014).

An important implication of this study is that infant and young child nutrition is important for policy beyond health. IYCF policies and practices should be considered within a broad and integrated food policy-sustainability framework, as well as being aligned with international nutrition and health standards and recommendations. This growing body of research about the greenhouse gas impact of human milk substitutes supports a greater policy focus on improving rates of exclusive and continued breastfeeding.

The growth of greenhouse gas emissions from milk formula illustrates well what has been described as the global "syndemic"—interacting health and nutrition problems of malnutrition, overnutrition, and climate change (Swinburn et al., 2019). The health costs of the global infant nutrition transition are already acknowledged and the crucial importance of actions to protect, promote, and support breastfeeding is also well established. Exclusive breastfeeding is already one of the WHO's "Double Duty Actions (DDA) for Nutrition" to tackle the double burden of malnutrition and obesity (WHO, 2017). However, improving breastfeeding could also directly address food system sustainability and the relevant Sustainable Development Goals.

Well established, effective interventions on breastfeeding are immediately available for integrated policy actions in all country settings (Sinha et al., 2015; Smith et al., 2018). For example, regulating marketing is one of the five DDAs. The WHO (2018) recently recommended stronger and more comprehensive national measures to regulate the marketing of commercial food products for infants and young children. Acknowledging the global nature of the greenhouse gas emission problem, as shown here for the Asia Pacific region, implies the need for regulations that also apply to MF exports (Galtry, 2013; Gribble & Smith, 2014).

The FAO has suggested foregrounding climate change when developing national dietary guidelines. Breastfeeding accords well with FAO requirements for "sustainable diets." For adult diets, nutritional adequacy goals may not be entirely compatible with high target levels of greenhouse gas emission reduction. For IYCF, however, there are no such trade-offs. A dietary shift towards more breastfeeding is "affordable," involving substantial financial savings on MF product expenditures compared to minimal outlays for breastfeeding (Sobel et al., 2012), including for the poorest families and countries. Food policies promoting breastfeeding advance social and health equity, and food security (Roberts et al., 2013; Salmon, 2015; Victora et al., 2016). Finally, regarding "cultural acceptability," breastfeeding has been the biological norm for feeding human infants and young children for over 125 million years of mammalian evolution, making it a universally "culturally acceptable" first food (Sellen, 2001). Policies to reverse current trends towards low optimal breastfeeding rates and high MF feeding could make a useful win/win contribution to food system sustainability in all country settings, especially for the most vulnerable. Breastfeeding is a "Triple Duty Action" (TDA) for sustainable diets and human and planetary health.

Limitations

Our results hinge on the validity of the Euromonitor data as an indicator of MF production levels and retail sales distribution for the years analyzed, as do other studies. The Euromonitor dataset available to the authors for this research was the 2013–2015 dataset, including Euromonitor projections for 2017. Our results for country emissions based on this dataset are only indicative if sales continue to grow (Baker et al., 2020). However, our estimates of greenhouse gas emission per kg remain valid for applying to other periods unless there are changes in the key parameters taken from the literature, which have underpinned our estimate. Also, like prior researchers, we excluded non-retail supply of MF (e.g., health facilities). This means considerable underestimation of greenhouse gas emissions (Smith et al., 1998).

Furthermore, our estimates are partial, and exclude post-manufacturing phases of the MF product life cycle. Although we estimate production-based results only, previous researchers have demonstrated the approximate equivalence of production-based and consumption-based estimates (Karlsson et al., 2019). Processing (e.g., blending), packaging, and transport during the production stage of SF add approximately 1.44 –1.84 kg CO^2 eq. per kg to greenhouse gas emissions for the consumer part of the life cycle (Karlsson et al., 2019). Karlsson and colleagues' estimate of emissions for infant formula (SF and SBFM) range from 5.3–8.5 kg CO_2 eq. per kg, after excluding processing, packaging, and transport greenhouse gas emissions.

This remains somewhat higher than our estimate for comparable phases of the product life cycle. The lower values in our study compared to the two other studies on this topic may be due to alternative assumptions about the composition of MF products. We used a generic model of composition, which was based on the Codex Alimentarius standards, while the North American study (Cadwell et al., 2020) used the Euromonitor recipe and its published ingredient estimates. Our study covered a diverse group of countries making it complex to use the actual composition of marketed products, and while the Karlsson et al. (2019) study recipe was also based on Codex Alimentarius standards, it made adjustments to reflect country manufacturing practices, and used some different ingredient emission values and assumptions.

Our sample selected high and low breastfeeding countries, and it is acknowledged that there are definitional issues about measuring breastfeeding rates across countries. Trends in retail sales of MF are an imperfect measure of consumption trends and may not correspond directly with breastfeeding trends, including because parents may use other foods or milks as human milk substitutes, and because of wastage. It is noted that the MF product sales data categories of 0–6 months for SBMF/SF and 7–36 months for FUF/TF may not reflect exactly the age of the child or year when the MF product is consumed.

Conclusion

Optimal breastfeeding is not only crucial to human nutrition and health, but its lower greenhouse gas emissions benefit planetary health. We have highlighted that breastfeeding policies, programs, and investments from the WHO/UNICEF *Global Strategy on Infant and Young Child Feeding* are an important but neglected element of strategies for sustainable food systems. Research is needed to provide better understanding and specific estimates of how achieving World Health Assembly global breastfeeding targets might align with international targets for lowering greenhouse gas emissions (WHO, 2014).

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*Editor's note

JHL has a policy of not publishing references from predatory publishers. The reference in the Reference List with * was published in a journal whose publisher has been criticized by some academics for low standards of peer review, as well as some allegations of academic misconduct. Others have felt these publishers have done their due diligence. Due to the importance of the topic covered in this review, we left the inclusion of these articles to the authors'

discretion. The authors have reviewed all references and take responsibility for their quality.

Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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