

APPROVED: 31 July 2019

doi: 10.2903/j.efsa.2019.e170917

Risk-Benefit Assessment of Foods

National Food Institute, Technical University of Denmark (DTU Food), Denmark,
R Assunção, SM Pires and M Nauta

Abstract

Food is an elementary requirement for human life, providing nutrients and essential energy needed for optimal health. But at the same time, food can also be a vehicle of hazardous substances or pathogens that could affect human health negatively. Risk-benefit assessment (RBA) of foods, a relatively new methodology for decision support, integrates nutrition, toxicology, microbiology, chemistry and human epidemiology for a comprehensive health impact assessment. By integrating health risks and benefits related to food consumption, RBA facilitates science-based decision-making in food-related areas and the development of policies and consumer advice. The present work programme aimed to allow the fellow to become acquainted with the process of RBA and the associated tools needed to assess quantitatively the risks and the benefits through three main activities (i) to learn the different methodologies used for RBA; (ii) to apply these methodologies to a specific case-study – RBA of raw milk consumption; and (iii) to participate in the main activities of the Risk-Benefit research group at DTU Food regarding risk-benefit issues. For the RBA of raw milk consumption, microbiological pathogens (*Listeria monocytogenes*, *Salmonella* spp., *Campylobacter jejuni* and Shiga toxin-producing *Escherichia coli*), probiotic bacteria and nutritional components (vitamins B2 and A) were considered, as well as the potential impact of raw milk consumption in the reduction of the allergies' prevalence. Two major approaches were applied: the bottom-up (estimating the disease incidence due to the exposure) and the top-down (using epidemiological and incidence data to estimate the number of cases attributable to a certain exposure). Through all the training and hands-on activities performed, the present work programme enabled the fellow to extend the knowledge on the quantitative RBA, specifically in the context of raw milk consumption. EU-FORA programme also provided an exceptional opportunity of networking and establishment of future research lines of collaboration.

© 2019 European Food Safety Authority. *EFSA Journal* published by John Wiley and Sons Ltd on behalf of European Food Safety Authority.

Keywords: Risk-benefit assessment, food, toxicology, microbiology, nutrition, raw milk

Correspondence: eu-fora@efsa.europa.eu

Acknowledgements: This report is funded by EFSA as part of the EU-FORA programme.

Suggested citation: National Food Institute, Technical University of Denmark (DTU Food), Denmark, Assunção R, Pires SM and Nauta M, 2019. Risk-Benefit Assessment of Foods. *EFSA Journal* 2019;17 (S2):e170917, 8 pp. <https://doi.org/10.2903/j.efsa.2019.e170917>

ISSN: 1831-4732

© 2019 European Food Safety Authority. *EFSA Journal* published by John Wiley and Sons Ltd on behalf of European Food Safety Authority.

This is an open access article under the terms of the [Creative Commons Attribution-NoDerivs License](#), which permits use and distribution in any medium, provided the original work is properly cited and no modifications or adaptations are made.



The EFSA Journal is a publication of the European Food Safety Authority, an agency of the European Union.



Table of contents

Abstract.....	1
1. Introduction.....	4
1.1. Risk-benefit assessment of foods.....	4
1.2. Risk-benefit assessment of raw milk consumption.....	5
2. Description of work programme.....	5
2.1. Aims.....	5
2.2. Training in risk-benefit assessment in foods.....	5
2.3. Risk-benefit assessment of raw milk consumption.....	6
2.4. Other activities related with risk-benefit assessment of foods.....	6
3. Conclusions.....	7
References.....	7
Abbreviations.....	8

1. Introduction

Food is an elementary requirement for human life, providing the nutrients and the essential energy needed for optimal health. At the same time, food may also be associated with adverse health effects, due to e.g. natural toxins, hazardous chemical substances or pathogenic microorganisms that could be present in foods and consequently affecting human health negatively. Moreover, dietary intake of specific nutrients in foods could be too low or too high, resulting in potential deficiencies or toxicity symptoms (Nauta et al., 2018). Therefore, methodologies and tools as risk-benefit assessment (RBA) constitute important contributions in the integrated research of risks and benefits, supporting the decision under food-related areas and in the development of food policies and consumer advice. The development of new food products and the support to consumers considering dietary changes are also important aspects that could take advantage of a RBA (Hoekstra et al., 2013).

1.1. Risk-benefit assessment of foods

Risk-benefit assessment of foods is a relatively new-decision support tool that intends to estimate the human health benefits and risks following exposure (or lack of exposure) to a particular food or food component and to integrate them in comparable measures (Boué et al., 2015; Pires et al., 2019). The beneficial and adverse health effects may occur concurrently from the intake of a single food item or a single food component, within the same population. This means that any policy action directed at the adverse effects also affects the degree of beneficial effects and vice versa. RBA integrates knowledge on nutrition, toxicology, microbiology, chemistry and human epidemiology for comprehensive health impact assessments (Pires et al., 2019). It constitutes one of the three pillars of the Risk-Benefit Analysis paradigm that combines RBA, risk-benefit management and risk-benefit communication, mirroring the risk analysis paradigm (EFSA Scientific Committee, 2010; Fransen et al., 2010; Nauta et al., 2018; Pires et al., 2019).

Figure 1 illustrates the proposed procedure for a RBA which consists of two separate and independent arms of assessing the risk and the benefit, respectively.

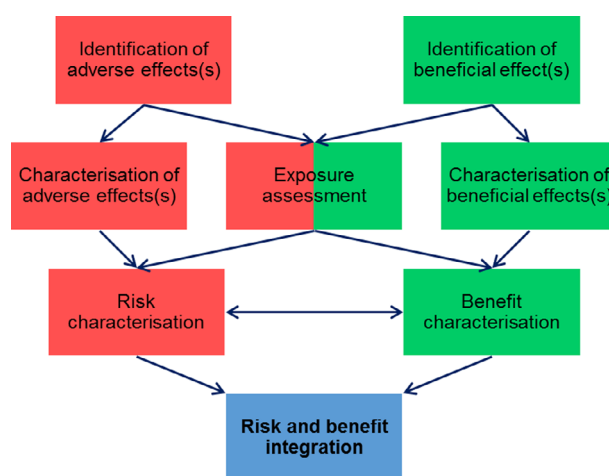


Figure 1: Risk-benefit assessment paradigm. Adapted from (EFSA Scientific Committee, 2010; Thomsen, 2019)

Generally, RBA process starts with the problem formulation corresponding to the clear description of the problem. The problem formulation, a critical step under RBA, should ensure that its outcome is useful and relevant (EFSA Scientific Committee, 2010). Under this step, the risk-benefit question (RBQ) should be defined, describing the purpose, scope and limitations of the assessment. Additionally, RBQ should define the population of interest, the level of aggregation (i.e. if the assessment should concern a food component, a food product or a diet) and the exposure scenarios (including the reference and the alternative scenarios). After the problem formulation, and based on the weight and quality of the scientific evidence, the identification of the health effects associated to the food component/food product/diet considered in the RBQ should be performed (identification of adverse/beneficial effect(s)). The relationship between the exposure to a food component or a food product and the associated health impact (usually known as dose-response assessment) should be established (characterisation of

adverse/beneficial effect(s)). For the considered scenarios, the exposure to the food component or food product should be assessed, using consumption data for the considered foods and concentration of the substances in the referred food products (exposure assessment). Combining the information regarding the dose–response relationship and the exposure assessment, the probability of occurrence of an adverse or beneficial health effect and the consequences of that effect should be estimated (risk characterisation; benefit characterisation). Finally, the risks and the benefits should be integrated, combining them if expressed in a common health metric, and the considered scenarios should be compared.

1.2. Risk-benefit assessment of raw milk consumption

Consumer demand for organic and natural foods, i.e. including minimal food processing, has been growing last years. Despite in the perception of some consumers these products are safer than the conventional, this is not necessarily correct (Claeys et al., 2013; Costard et al., 2017). Some evidences of high rates of food-borne illnesses associated to some 'natural foods' as, e.g. raw milk, reflect that despite the increase popularity, these food products are not exempt of risks.

According to the Regulation (EC) No 853/2004, raw milk is defined as milk produced by the secretion of the mammary gland of farmed animals that has not been heated to more than 40°C or undergone any treatment that has an equivalent effect (European Commission, 2004). Regarding the consumption of raw milk, there is currently a debate on the potential health benefits when compared to pasteurised milk. The preference to the raw milk is mainly associated with several perceived health benefits that are believed to be destroyed upon heating. Claimed health benefits are, e.g. 'higher nutritional value', especially in terms of vitamins' contents, 'beneficial microflora' as probiotic bacteria, and 'allergy prevention'. Oppositely, there are significant concerns by regulatory and public health organisations regarding the potential risk of contracting milk-borne diseases due to raw milk contamination with human pathogens. Although some previous studies compared the health risks and benefits of raw milk, and found that the risks are larger than the benefits, the overall health effect of drinking raw milk instead of pasteurised milk has never been quantified, and the benefits compared to the risks continue to be an issue for debate.

2. Description of work programme

2.1. Aims

The present work programme was prepared to allow the fellow to become acquainted with the process of RBA of foods and the associated tools needed to assess the risks and the benefits in a quantitative way. In order to attain this core objective, three main specific objectives were considered, namely: (i) to learn the different steps of RBA and the different methodologies applicable to estimate the risks and benefits associated to foods; (ii) to apply these process and methodologies to a specific case-study; and (iii) to integrate the main activities of the research group regarding different risk-benefit issues. The entire work programme was carried out in the Research Group for Risk-Benefit of the National Food Institute, Technical University of Denmark (DTU Food).

The case-study selected to be performed under the present work programme was the quantitative RBA of raw milk consumption. In addition to the originality of this work, the added value of such a quantitative assessment is that consumers can be informed on the magnitude of the risk and the expected health impact, and make informed decisions based in scientific evidence.

2.2. Training in risk-benefit assessment in foods

As an initial step of the training process in the RBA of foods, some literature search regarding the methodology and the different aspects of RBA was performed. The main aspects of RBA were discussed in one-to-one meetings between the fellow and his supervisor. In order to deeper learn and harmonise the concepts and methodologies of RBA of foods, namely to identify and quantify beneficial and adverse health effects of foods, food constituents or nutrients, and to measure their risk-benefit balance, the fellow attended the course 'Risk-Benefit Assessment in Foods: methods for quantifying health effects' (November 6–15, 2018, Lyngby, Denmark). This 8-day intensive course was taught by Maarten Nauta (supervisor of the present work programme and the course responsible) and other researchers from the Research Group for Risk-Benefit from DTU Food. The course considered a total study load of 2.5 ECTS (equivalent to 70 h of study). In addition to theoretical lectures, hands-on

exercises, group works and discussions were used to introduce the RBA and its steps, covering chemical, microbiological and nutritional important perspectives for RBA. Additional aspects as burden of disease and disability-adjusted life years (DALY) calculations, quantitative and stochastic assessment and variability and uncertainty were also addressed.

2.3. Risk-benefit assessment of raw milk consumption

The objective of this assessment was to quantify the risk-benefit balance and the health impact of raw milk consumption in terms of DALY. A stepwise approach was used to perform the RBA of raw milk consumption, following the scheme described previously by EFSA (Figure 1). Firstly, the problem was defined, stating the scope of the assessment and the RBQ to be answered. The scenarios to be considered were also described, including a reference (corresponding to the consumption of pasteurised milk) and an alternative scenarios (corresponding to the consumption of raw milk). Through literature review, different components usually present in milk (raw and/or pasteurised) were identified and the associated health effects were selected. In addition to the literature search, specific documents produced by national and international authorities were considered (Ministry for Primary Industries, 2013a,b; EFSA BIOHAZ Panel, 2015). Some criteria of inclusion and exclusion were established for the identification of the health effects associated to the considered food components and particular attention was dedicated to the degree of evidence and quality of data. The microbiological hazards *Listeria monocytogenes*, *Salmonella* spp., *Campylobacter jejuni* and Shiga toxin-producing *Escherichia coli* (STEC) were considered next to potentially beneficial components such as probiotic bacteria (*Lactobacillus* species) and vitamins B2 and A. The potential effect of the consumption of raw milk in the reduction of the prevalence of allergies was also considered as a potential beneficial effect of raw milk consumption. Mathematical modelling, including predictive modelling of bacterial inactivation and growth and modelling of dose–response using epidemiological data, were used to quantify the DALYs associated to the consumption of raw milk directly from vending machines. Two major approaches were applied: (i) the bottom-up approach estimating the incidence of disease due to the exposure via dose-response models (used for the microbiological hazards); and (ii) the top-down approach that starts from the epidemiological and incidence data and estimates the number of attributable cases of a certain disease due to an exposure (used for the nutritional components) (Nauta et al., 2018). Published data were used to perform the exposure assessment. BCoDE, software developed by the European Centre for Disease Prevention and Control (ECDC), was used to estimate the associated DALYs (ECDC, 2019). Dutch food composition database was used to estimate the vitamins A and B2 intake through milk consumption. Modelling resources and the GBD Results Tool were used to establish the associated risk prevention and to estimate the associated DALYs, respectively. Finally, the integration of risks and benefits expressed in DALYs was obtained, comparing the considered different scenarios, through the calculation of the difference between alternative and reference scenarios (expressed in Δ DALY). Due to the assumptions and approximations included in the RBA model, required to accommodate the lack of knowledge or data, the associated uncertainty was identified and characterised.

Some of the obtained results were presented orally in the division seminar at DTU Food, and also as a case study in the Parma Summer School 'Risk-benefit in food safety and nutrition' (June 11–13, 2019, Parma, Italy).

2.4. Other activities related with risk-benefit assessment of foods

Additional activities were accomplished related with the main goal of the present work programme – the establishment of a solid knowledge foundation under RBA. Integrating the usual activities of the research group, the fellow also attended and participated actively in the weekly group meetings, journal club (every month) and scientific division meetings (every 14 days). Regarding the journal club, a presentation and associated discussion of a paper related with the health effects associated with Mediterranean diet was performed.

RiskBenefit4EU (RB4EU), a collaborative project, funded by EFSA under the Partnering Grants, joins together DTU Food and National Institute of Health Dr. Ricardo Jorge (fellow's home institution). Taking advantage of some planned activities of RB4EU, the fellow also participated in training on RBA, collaborated in the organisation and mentoring of a short-term scientific mission from Portugal to DTU and in the development of a case-study in the RBA of cereal-based foods intended to be consumed by young children.

A quick quantitative RBA of nuts in Portugal was also performed and the obtained results were presented orally in an international conference (41st Mycotoxins Workshop, May 6–8, 2019, Lisboa, Portugal).

The fellow is also part of the team responsible to perform a systematic review on the RBAs of fish, developed under the International Network on Risk-Benefit Assessment of Foods.

3. Conclusions

On a broader perspective, research in RBA of foods is promising and future evolution is expected. The present work programme developed at the Research Group for Risk-Benefit of the National Food Institute, Technical University of Denmark, had as main focus the capacitation of the fellow in the RBA of foods. The programme provided the opportunity to get a thorough insight into the work performed in an international research group dealing with RBA. Through all the activities performed, the present work programme enabled the fellow to gain first-hand experience on RBA, extending the knowledge on the quantitative RBA of raw milk consumption. Detailed description of the outputs obtained in the RBA of raw milk consumption will be made available in a peer-reviewed publication.

In addition to the scientific achievements regarding the acquired knowledge through training as well as the hands-on activities, the EU-FORA programme also provided an exceptional opportunity of networking and establishment of future research lines of collaboration. In a pleasant and multicultural atmosphere, DTU Food provided the expertise, mentoring as well as working conditions, promoting the ideal environment to knowledge exchange and research on food safety and nutrition domains. For these reasons, DTU Food is completely aligned with the purposes of the EU-FORA programme and an adequate host site for future fellows.

References

- Boué G, Guillou S, Antignac J-P, Bizet B and Membré J-M, 2015. Public Health Risk-benefit Assessment Associated with Food Consumption—A Review. *European Journal of Nutrition & Food Safety*, 5, 32–58. <https://doi.org/10.9734/ejnfs/2015/12285>
- Claeys WL, Cardoen S, Daube G, De Block J, Dewettinck K, Dierick K and Herman L, 2013. Raw or heated cow milk consumption: review of risks and benefits. *Food Control*, 31, 251–262. <https://doi.org/10.1016/j.foodcont.2012.09.035>
- Costard S, Espejo L, Groenendaal H and Zagmutt FJ, 2017. Outbreak-Related Disease Burden Associated with Consumption of Unpasteurized Cow's Milk and Cheese, United States, 2009–2014. *Emerging Infectious Diseases*, 23, 957–964. <https://doi.org/10.3201/eid2306.151603>
- ECDC (European Centre for Disease Prevention and Control), 2019. BCoDE toolkit [software application]. Version 1.7. Solna: European Centre for Disease Prevention and Control. Available online: <https://ecdc.europa.eu/en/publications-data/toolkit-application-calculate-dalys>
- EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards), 2015. Scientific Opinion on the public health risks related to the consumption of raw drinking milk. *EFSA Journal* 2015;13(1):3940, 95 pp. <https://doi.org/10.2903/j.efsa.2015.3940>
- EFSA Scientific Committee, 2010. Guidance on human health risk-benefit assessment of foods. *EFSA Journal* 2010;8(7):1673, 40 pp. <https://doi.org/10.2093/j.efsa.2010.1673>
- European Commission, 2004. Regulation laying down specific hygiene rules for the hygiene of foodstuffs, 853/2004/EC.
- Fransen H, De Jong N, Hendriksen M, Mengelers M, Castenmiller J, Hoekstra J, van Leeuwen R and Verhagen H, 2010. A tiered approach for risk-benefit assessment of foods. *Risk Analysis*, 30, 808–816. <https://doi.org/10.1111/j.1539-6924.2009.01350.x>
- Hoekstra J, Hart A, Owen H, Zeilmaker M, Bokkers B, Thorgilsson B and Gunnlaugsdottir H, 2013. Fish, contaminants and human health: quantifying and weighing benefits and risks. *Food and Chemical Toxicology*, 54, 18–29. <https://doi.org/10.1016/j.fct.2012.01.013>
- Ministry for Primary Industries, 2013a. An Assessment of the Effects of Pasteurisation on Claimed Nutrition and Health Benefits of Raw Milk. Wellington.
- Ministry for Primary Industries, 2013b. Assessment of the microbiological risks associated with the consumption of raw milk. New Zealand. Retrieved from Ministry for Primary Industries, Wellington.
- Nauta MJ, Andersen R, Pilegaard K, Pires SM, Ravn-Haren G, Tetens I and Poulsen M, 2018. Meeting the challenges in the development of risk-benefit assessment of foods. *Trends in Food Science & Technology*, 76, 90–100. <https://doi.org/10.1016/j.tifs.2018.04.004>
- Pires SM, Boué G, Boobis A, Eneroth H, Hoekstra J, Membré J-M, Persson IM, Poulsen M, van Klaveren Thomsen ST and Nauta MJ, 2019. Risk Benefit Assessment of foods: key findings from an international workshop. *Food Research International*, 116, 859–869. <https://doi.org/10.1016/j.foodres.2018.09.021>

Thomsen ST, 2019. Risk-benefit assessment of food substitutions. Technical University of Denmark. Available online: [http://orbit.dtu.dk/en/publications/riskbenet-assessment-of-food-substitutions\(b8150e23-9548-4449-ada1-7daa663489a6\).html](http://orbit.dtu.dk/en/publications/riskbenet-assessment-of-food-substitutions(b8150e23-9548-4449-ada1-7daa663489a6).html)

Abbreviations

DALY	Disability-adjusted life years
DTU Food	National Food Institute, Technical University of Denmark
ECDC	European Centre for Disease Prevention and Control
RB4EU	RiskBenefit4EU
RBA	risk-benefit assessment
RBQ	risk-benefit question
STEC	Shiga toxin-producing <i>Escherichia coli</i>