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Safety of dried fruits of *Synsepalum dulcificum* as a novel food pursuant to Regulation (EU) 2015/2283

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Abstract

Following a request from the European Commission, the EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA) was asked to deliver an opinion on dried fruits of *Synsepalum dulcificum* as a novel food (NF) pursuant to Regulation (EU) 2015/2283. The NF is pitted and dried (by lyophilisation) fruits of *S. dulcificum*. The NF contains the glycoprotein miraculin ($\leq 2.5\%$) which causes sour and acidic foods to taste sweet. The fruits have a documented history of consumption in Africa and products thereof can be found in different markets worldwide. Information on the production process and the composition of the NF is sufficient and does not raise safety concerns. The applicant proposes to use the NF as or in food supplements for the adult population, excluding pregnant and lactating women, at a maximum daily amount of 0.9 g. Taking into account these conditions of use, the Panel considers that the consumption of the NF is not nutritionally disadvantageous. The provided genotoxicity studies do not raise concerns for genotoxicity of the NF. The Panel concludes that the only dose tested in a 90-day oral toxicity study of 2,000 mg/kg body weight (bw) per day was not associated with adverse effects. By applying an uncertainty factor of 200, the Panel concludes that the NF is safe at an intake level of 10 mg/kg bw per day, corresponding to a maximum daily intake of 0.7 g of the NF for the target population, rather than 0.9 g/day as proposed by the applicant.

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1. Introduction

1.1. Background and Terms of Reference as provided by the European Commission

On 14 November 2018, the company Baia Food Co. (Medicinal Gardens S.L.) submitted a request to the European Commission in accordance with Article 10 of Regulation (EU) 2015/2283¹ to place dried fruits of *Synsepalum dulcificum* on the Union market as a novel food.

The novel food (dried fruits of *S. dulcificum*) is intended to be used as or in food supplements. The target population is the adult population.

On 25 March 2019 and in accordance with Article 10(3) of Regulation (EU) 2015/2283, the Commission asked EFSA to provide a scientific opinion by carrying out the safety assessment for dried fruits of *S. dulcificum* as a NF in the context of Regulation (EU) 2015/2283.

2. Data and methodologies

2.1. Data

The safety assessment of this novel food (NF) is based on data supplied in the application, information submitted by the applicant following EFSA's requests for supplementary information and information provided by the EFSA Working Group on Compendium of Botanicals.

Administrative and scientific requirements for NF applications referred to in Article 10 of Regulation (EU) 2015/2283 are listed in Commission Implementing Regulation (EU) 2017/2469².

A common and structured format on the presentation of NF applications is described in the EFSA guidance on the preparation and presentation of a NF application (EFSA NDA Panel, 2016). As indicated in this guidance, it is the duty of the applicant to provide all available (proprietary, confidential and published) scientific data, including both data in favour and not in favour to support the safety of the proposed NF.

This NF application includes a request for the protection of proprietary data in accordance with Article 26 of Regulation (EU) 2015/2283. The data, requested by the applicant to be protected, comprise: toxicological information (studies on acute toxicity, genotoxicity and sub-chronic toxicity), human study and compositional studies.

2.2. Methodologies

The assessment follows the methodology set out in the EFSA guidance on NF applications (EFSA NDA Panel, 2016) and the principles described in the relevant existing guidance documents from the EFSA Scientific Committee. The legal provisions for the assessment are laid down in Article 11 of Regulation (EU) 2015/2283 and in Article 7 of Commission Implementing Regulation (EU) 2017/2469.

The information provided by the EFSA Working group on Compendium of botanicals is based on an extensive literature search on fruits of *S. dulcificum* using the following scientific databases: 'Scopus', 'Pubmed', 'Scifinder' and 'Web of Science'. This provided the basis for identifying scientific evidence available in peer-reviewed scientific papers in relation to substances contained in previously mentioned fruits of potential concerns, toxicological data and studies reporting adverse health outcomes in humans.

This assessment concerns only the risk that might be associated with the consumption of the NF under the proposed conditions of use and is not an assessment of the efficacy of the NF with regard to any claimed benefit.

3. Assessment

3.1. Introduction

The NF, which is the subject of the application, is lyophilised pulp and skin of pitted fruits of *S. dulcificum* (Schumach. & Thonn) Daniell that belong to the family of Sapotaceae.³

¹ Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001. OJ L 327, 11.12.2015, p. 1.

² Commission Implementing Regulation (EU) 2017/2469 of 20 December 2017 laying down administrative and scientific requirements for applications referred to in Article 10 of Regulation (EU) 2015/2283 of the European Parliament and of the Council on novel foods. OJ L 351, 30.12.2017, pp. 64–71.

³ <http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:789924-1>

The NF falls under Regulation 2015/2283, Article 3(2)(a)(iv): food consisting of, isolated from or produced from plants or their parts.

The NF is proposed by the applicant to be used as or in food supplements. The target population is the adult population (except pregnant and lactating women).

3.2. Identity of the NF

The NF, named by the applicant 'Dried miracle berries, DMB' is pitted and dried (by lyophilisation) fruits of *S. dulcificum*.

The plant *S. dulcificum* is native to the forest regions of tropical West Africa and it can be found growing wild across the coast of the Gulf of Guinea (Juhé-Beaulaton, 2014). Fruits contain a glycoprotein called miraculin, responsible for a taste-modifying effect which causes sour and acidic foods to taste sweet (Kurihara and Beidler, 1968).

Miraculin is a protein consisting of 220 amino acids (Masuda et al., 1995) which belongs to the Kunitz-type soybean trypsin inhibitor (STI) family, but has lost its STI activity (Takai et al., 2013). It has a molecular weight of 24.6 kDa of which up to 13.9% (3.4 kDa) is represented by the sugar moiety, including glucosamine (31%), mannose (30%), fucose (22%), xylose (10%) and galactose (7%) (Theerasilp et al., 1989). It naturally occurs as a tetramer (98.4 kDa), a combination of four monomers grouped into two dimers bound by a disulfide bond.

Sanematsu et al. (2016) proposed a mechanistic model underlying the taste modifying effect of miraculin. It can bind to the amino-terminal domain of the human sweet taste receptor hTAS1R2 as an inactive form at neutral pH. Extracellular acidification protonates miraculin and the extracellular region of hTAS1R2, inducing partial activation of the sweet taste receptor. Membrane crossing of an unprotonated form of weak acids exerts further protonation of the intracellular domain of the sweet taste receptor leading to the full receptor activation.

3.3. Production process

The applicant provided a description of the production process, which follows Hazard Analysis Critical Control Points (HACCP) principles and general hygiene requirements. All materials in contact with the NF comply with applicable Union and National legislation on food contact materials.

The fruits are acquired from smallholder farms located in Ghana. They are manually harvested from mature cultivated plants, sorted, precooled and sent for the manufacturing process. Then, they are sorted once again, cleaned with demineralised tap water, and pitted mechanically. The remaining skins and pulps are then frozen and prepared for transport to the facility located in EU where they are dried by lyophilisation to preserve heat-sensitive compounds. The resulting dried cake is finally milled into a powder and stored.

The Panel considers that the production process is sufficiently described and does not raise safety concerns.

3.4. Compositional data

The NF mainly consists of carbohydrates (up to 86.3%), and smaller amounts of proteins (up to 6%) and fats (up to 3.2%). According to the applicant, the key characteristic component of the NF is miraculin, a glycoprotein which can be found in amounts up to 2.5%.

In order to confirm that the manufacturing process is reproducible and adequate to produce on a commercial scale a product with certain characteristics, the applicant provided analytical information for five independent batches of the NF for proximate analyses and heavy metals (Table 1). Due to high contamination levels reported for some microbial parameters (data not shown), the production process was updated to the one described under Section 3.3 *Production process* in order to reduce the microbial content. Microbial parameters were analysed in seven new batches of the NF (Table 2).

Table 1: Batch-to-batch analyses of the NF

| Parameter (unit) | Batch no | | | | | Method/technique |
|------------------------------|-------------------|-------------------|-------------------|---------|---------|---------------------------------------|
| | #1 ^(a) | #2 ^(a) | #3 ^(a) | #4 | #5 | |
| Proximate analysis (g/100 g) | | | | | | |
| Moisture | 2.57 | 5.27 | 3.73 | 5.20 | 5.20 | Gravimetric |
| Ash | 3.70 | 3.53 | 4.23 | 5.00 | 5.40 | Gravimetric |
| Total carbohydrate | 86.3 | 81.0 | 77.7 | 79.4 | 80.6 | Calculation |
| Sugars ^(b) | 72.5 | 66.0 | 64.9 | 56.5 | 67.2 | Ion chromatography/pulsed amperometry |
| Total protein | 5.03 | 5.10 | 6.00 | 5.30 | 4.20 | Kjeldahl ^(c) |
| Total fat | 2.47 | 3.20 | 2.73 | < 0.50 | 1.8 | Gravimetric |
| Saturated fatty acids | 1.1 | 1.33 | 0.70 | < 0.10 | 0.80 | GC-FID |
| Polyunsaturated fatty acids | 0.7 | 1.23 | 1.2 | < 0.10 | 0.6 | GC-FID |
| Monounsaturated fatty acids | 0.63 | 0.63 | 0.8 | < 0.10 | 0.4 | GC-FID |
| Sodium chloride | 0.029 | 0.021 | 0.036 | 0.043 | 0.037 | ICP-MS spectroscopy |
| Fibre | - | 1.9 | 5.6 | 5.1 | 2.8 | Gravimetric |
| Energy (kJ/100 g) | 1,619 | 1,597 | 1,569 | 1,481 | 1,531 | Calculation |
| Energy (kcal/100 g) | 387 | 377 | 371 | 349 | 361 | Calculation |
| Heavy metals | | | | | | |
| Arsenic (mg/kg) | < 0.03 | < 0.03 | < 0.03 | < 0.03 | < 0.03 | ICP-MS |
| Cadmium (mg/kg) | 0.069 | 0.063 | 0.14 | 0.088 | 0.070 | |
| Mercury (mg/kg) | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | |
| Lead (mg/kg) | < 0.04 | < 0.04 | < 0.04 | < 0.04 | < 0.04 | |

GC-FID: gas chromatography with flame-ionisation detection; ICP-MS: inductively coupled plasma mass spectrometry.

(a): Analyses done in triplicates.

(b): Total of glucose, fructose, saccharose, maltose and lactose.

(c): Total nitrogen \times 6.25.**Table 2:** Microbiological quality of the NF

| Parameter (unit) | Batch no | | | | | | | Method |
|---|----------|---------------------|-------|-------------------|-------|-------------------|-------------------|---|
| | #9 | #10 | #11 | #12 | #13 | #14 | #15 | |
| Microbial parameters (CFU/g) | | | | | | | | |
| Total aerobic plate count | 1,100 | 4,600 | 6,900 | 380 | 5,900 | 45 ^(b) | 82 ^(b) | Internal method based on UNE EN ISO 4833-1 |
| Presumptive <i>Bacillus cereus</i> | < 40 | < 40 | < 10 | < 10 | < 10 | < 10 | < 10 | Colony count/BKR 23/06-02/10/ UNE EN-ISO 7932:2005 |
| Sulfite-reducing <i>Clostridia</i> | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | Internal method based on ISO 15213 |
| Enterobacteriaceae | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | Internal method based on UNE EN ISO 21528-2 |
| Yeasts and moulds | 370 | < 10 | 100 | 40 ^(b) | 150 | 60 ^(b) | 100 | Internal method based on ISO 21527-1 and ISO 21527-2 |
| Staphylococci coagulase + | < 10 | < 10 ^(a) | < 10 | < 10 | < 10 | < 10 | < 10 | Internal method based on ISO 6888-2 |
| <i>Escherichia coli</i> β glucuronidase + | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | Internal method based on chromidID™ Coli Agar (COLI ID-F) |
| Faecal coliforms | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | Internal method based on chromidID™ Coli Agar (COLI ID-F) |

CFU: colony forming units.

(a): Reported as *Staphylococcus aureus* count.

(b): Estimated count.

The applicant also provided mineral contents measured by inductively coupled plasma/mass spectrometry or optical emission spectroscopy (ICP-MS or ICP/OES) and fatty acid profiles measured by gas chromatography with flame-ionisation detection (GC-FID) of the same first five independent batches of the NF (data not shown).

Furthermore, the applicant performed a determination of the total polyphenolic content of three different batches of the NF, using spectrophotometry (Folin–Ciocalteu) (Table 3).

Table 3: Total polyphenolic content in the NF

| Parameter (unit) | Batch no ^(a) | | | Analytical technique |
|------------------------------|-------------------------|------|------|----------------------|
| | #1 | #2 | #6 | |
| Total polyphenols (mg GAE/g) | 4.25 | 4.54 | 4.20 | Spectrophotometry |

GAE: Gallic acid equivalents.

(a): Analyses done in triplicates.

The applicant used a validated in-house method based on proton nuclear magnetic resonance (¹H-NMR) analysis (which captures part of the glycosylation pattern of miraculin) to quantify miraculin in five different batches of the NF. The results were presented as the percentage of miraculin present in the NF (w/w) (Table 4).

Table 4: Content of miraculin in the NF

| Parameter (unit) | Batch no | | | | | Analytical technique |
|--------------------------------|----------|-----|-----|-----|-----|----------------------|
| | #1 | #2 | #5 | #6 | #7 | |
| % of miraculin in the NF (w/w) | 1.7 | 1.7 | 2.1 | 1.8 | 2.0 | ¹ H-NMR |

¹H-NMR: proton nuclear magnetic resonance.

The results showed the range of miraculin between 1.7% and 2.1% of the total weight of the NF.

Additionally, the applicant provided concentrations of polycyclic aromatic hydrocarbons (PAHs) in four independent batches of the NF, measured by gas chromatography–mass spectrometry (GC–MS) which were below maximum levels for PAHs in food supplements.⁴

Concentrations of chlorate were quantified in batches of the NF in amounts up to 0.046 mg/kg but are not above the maximum residue level for berries and small fruits (0.05 mg/kg).⁵

Regarding concentrations of mycotoxins, the applicant provided certificates of analyses by liquid chromatography with tandem mass spectrometry (LC–MS/MS) for five independent batches of the NF and no results (data not shown) exceeded maximum levels in regulated foods (Regulation (EC) No 1881/2006).

EFSA retrieved a study by Njoku et al. (2016), which reported the occurrence of alkaloids and of some antinutrients in the pulp of *S. dulcificum* fruits. Upon a request to comment on these findings, the applicant provided an analytical report on the content of oxalates, trypsin inhibitor and pyrrolizidine alkaloids in three different batches of the NF (Table 5). The applicant also submitted a study by Menéndez-Rey et al. (2021) in which the concentration of lectins in three batches of the NF was quantified by haemagglutination assays in human blood.

Table 5: Content of oxalates, trypsin inhibitor and pyrrolizidine alkaloids in the NF

| Parameter (unit) | Batch no | | | Analytical technique |
|-------------------------------|--|--|--|----------------------|
| | #5 | #7 | #8 | |
| Oxalic acid (g/100 g) | 0.06 ^(a) 0.09 ^(b) | 0.07 ^(a) 0.10 ^(b) | 0.05 ^(a) 0.07 ^(b) | HPLC |
| Trypsin inhibitor (TIU/mg dw) | 0.80 | 0.81 | 0.97 | UV-VIS |

⁴ Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. OJ L 364, 20.12.2006, p. 5.

⁵ Commission Regulation (EC) No 2020/749 of 4 June 2020 amending Annex III to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for chlorate in or on certain products. OJ L 178/7, 8.6.2020, p. 14.

| Parameter (unit) | Batch no | | | Analytical technique |
|---|----------|--------------|--------------|----------------------|
| | #5 | #7 | #8 | |
| Sum of pyrrolizidine alkaloids (LB, µg/kg) ^{(c),(d)} | 7.2 | Not detected | Not analysed | LC-MS/MS |

TIU: trypsin inhibitor unit; dw: dry weight; LB: lower bound; HPLC: high-performance liquid chromatography; UV-VIS: ultraviolet-visible; LC-MS/MS: liquid chromatography-tandem mass spectrometry; LOQ: limit of quantification.

(a): Expressed as oxalic acid.

(b): Expressed as calcium oxalate.

(c): Also quantified in the batch #1 in amount of 5.6 µg/kg.

(d): Analyses of 21 pyrrolizidine alkaloids were performed (LOQ range 0.5–2 µg/kg).

According to the reported results, the amounts of oxalic acid in the NF ranged between 0.05 and 0.07 g/100 g (i.e. 500 and 700 mg/kg). EFSA (2018) noted the oxalate content in fonio (*D. exilis*) and wheat bran of 2,600 and 4,600 mg/kg, respectively. Trypsin inhibitor content in the NF varied between batches (0.80–0.97 TIU/mg dw), but was lower than those reported in chia seeds (13 TIU/mg dw) by De Souza et al. (2017), and in soybean (43–84 TIU/mg) and common bean (21–28 TIU/mg) by Guillamon et al. (2008). The sum of pyrrolizidine alkaloids in the NF was quantified in amounts up to 7.2 µg/kg, which is below the future maximum level for food supplements of 400 µg/kg.⁶ Haemagglutinating activity of the NF was low and comparable with the activity of blueberries and raspberries (Menéndez-Rey et al., 2021).

The Panel considers that the information provided on the composition is sufficient for characterising the NF.

3.5. Stability

In order to demonstrate the stability of the NF, the applicant conducted a study of shelf-life under normal storage conditions (20 ± 2°C, relative humidity 50 ± 10%) over a 24-month period with one batch of the NF (#1). Sensory parameters (smell, colour, flavour and texture) were not changed throughout the whole testing period (data not shown), while changes in moisture, water activity and pH were similar (Table 6). Furthermore, microbial parameters were measured in the 6th, 12th and 24th month of the study (Table 7).

Table 6: Physicochemical stability of batch #1 of the NF

| Parameter (unit) | t (months) | | | | Method |
|--------------------|------------|------|------|------|------------------|
| | 0 | 7 | 12 | 24 | |
| Moisture (g/100 g) | 1.8 | 1.1 | 2.4 | 2.7 | Thermogravimetry |
| Water activity | 0.11 | 0.11 | 0.13 | 0.12 | Hygrometric |
| pH | 3.2 | 3.7 | 3.2 | 3.3 | Potentiometric |

Table 7: Microbial stability of batch #1 of the NF

| Microbial parameters (CFU/g) | t (months) | | | Method |
|--|-------------------|---------|-------------------|-------------------------------|
| | 6 | 12 | 24 | |
| Moulds | 55 ^(a) | < 10 | 91 ^(a) | Plate count/ISO 21527-2 2008 |
| Yeasts | < 400 | < 10 | < 10 | Plate count/21527-2 2008 |
| <i>Escherichia coli</i> β-glucuronidase+ count | < 10 | < 10 | < 10 | Plate count/ISO 16649-2:02 |
| Positive coagulase staphylococci count | < 10 | < 10 | < 10 | Plate count/ISO 6888-1:00 |
| Presumptive <i>Bacillus cereus</i> | 40 | < 10 | 400 | Plate count/ISO 7932-2:05 |
| <i>Listeria monocytogenes</i> (in 25 g) | Absence | Absence | Absence | Real time PCR/Internal method |
| <i>Salmonella</i> spp (in 25 g) | Absence | Absence | Absence | Real time PCR/Internal method |

CFU: colony forming units; PCR: polymerase chain reaction.

(a): Estimated value.

⁶ Commission Regulation (EU) No 2020/2040 of 11 December 2020 amending Regulation (EC) No 1881/2006 as regards maximum levels of pyrrolizidine alkaloids in certain foodstuffs. OJ L 420/1, 14.12.2020, p. 1–4.

In order to further support the stability of the NF, the applicant conducted additional analyses on four batches of the NF, each batch tested only at one time point (Table 8). The applicant also submitted results of sensory analyses for those four batches of the NF which reported no changes (data not shown).

Table 8: Stability of four different batches of the NF

| Parameter (unit) | Batch No | | | | Method |
|--|-----------|-----------|-----------|-----------|---|
| | #7 | #2 | #1 | #6 | |
| t (months) | 18 | 26 | 30 | 36 | |
| Microbial parameters (CFU/g) | | | | | |
| Aerobic microorganism count | 4,100 | 11,000 | 3,500 | 3,700 | Internal method based on EN ISO 4833-1 |
| Moulds and yeasts count | < 40 | < 10 | < 10 | < 10 | Internal method based on ISO 21527-2 |
| Enterobacteriaceae count | < 10 | < 10 | < 10 | < 10 | Internal method based on EN ISO 21528-2 |
| Total coliform count | < 10 | < 10 | < 10 | < 10 | Internal method based on chromID™ Coli Agar (COLI ID-F) |
| <i>Escherichia coli</i> β-glucuronidase+ count | < 10 | < 10 | < 10 | < 10 | Internal method based on chromID™ Coli Agar (COLI ID-F) |
| Positive coagulase staphylococci count | < 10 | < 10 | < 10 | < 10 | Internal method based on ISO 6888-2 |
| Physico-chemical parameters | | | | | |
| Water activity | 0.125 | 0.129 | 0.138 | – | |
| pH | 3.1 | 3.0 | 3.3 | – | |

The applicant also conducted a stability test of the NF to temperature and pH. The aim of the study was to determine whether varying temperature or pH conditions will denature and consequently inactivate miraculin. The volunteers tested taste-modifying properties of the NF after the NF was exposed to different temperatures (at –80, –20, 4, 20, 37 and 60°C) for 1 h or 10 min (n = 10). The results indicated a loss of taste-modifying properties of the NF at 60°C, which could not be restored anymore. A pH stability assay suggested that miraculin is stable and functional at pH 2–10.

The Panel notes that stability data in Tables 7 and 8 refer to the batches of NF produced with the initial production process, and thus not all microbial parameters at every time point measured were consistent or in line with the specifications of the NF. However, considering physico-chemical characteristics of the NF, as well as the fact that the applicant produced new batches of the NF of acceptable microbiological quality (Table 2), the Panel considers the provided stability data as sufficient.

3.6. Specifications

The specifications of the NF are indicated in Table 9.

Table 9: Specifications of the NF

| Description: The NF is lyophilised pulp and skin of pitted fruits of <i>Synsepalum dulcificum</i> (Schumacher & Thonn) Daniell | |
|---|---------------|
| Parameter (Unit) | Specification |
| Moisture (g/100 g) | < 6 |
| Ash (g/100 g) | 3.5–8.5 |
| Total carbohydrates (g/100 g) | 70–87 |
| Sugars (g/100 g) | 50–75 |
| Fibre (g/100 g) | 1–6.5 |
| Total protein (g/100 g) | 3.5–6.0 |
| Total fat (g/100 g) | > 0.50–3.50 |
| Saturated fatty acids (g/100 g) | > 0.20–1.40 |
| Sodium chloride (g/100 g) | 0.015–0.045 |

Description: The NF is lyophilised pulp and skin of pitted fruits of *Synsepalum dulcificum* (Schumacher & Thonn) Daniell

| Parameter (Unit) | Specification |
|--------------------------------------|---------------|
| Energy (kJ/100 g) | 1,180–1,620 |
| Energy (kcal/100 g) | 282–387 |
| Total polyphenols (mg/g) | 4–5 |
| Miraculin (%) | 1.5–2.5 |
| Total aerobic count | < 10,000 |
| <i>Bacillus cereus</i> (presumptive) | < 100 |
| Sulfite-reducing <i>Clostridia</i> | ≤ 30 |
| Total Enterobacteriaceae | < 100 |
| Moulds and yeasts | < 500 |

3.7. History of use of the NF and/or of its source

3.7.1. History of use of the source

There is a documented history of consumption of fruits of *S. dulcificum*, which were consumed by natives of Western and Central Africa, since the 18th century (Labat, 1730; Dalziel, 1967; Juhé-Beaulaton, 2014). The fruits were mainly consumed prior to eating meals for altering their taste.

According to the applicant, nowadays *S. dulcificum* is mainly cultivated in Asia (Taiwan and China), the USA and Latin America (Ecuador, Colombia and Puerto Rico), with cultivation declining in its native African regions (the Gulf of Guinea). The fruits and products thereof are available in different forms (as fresh and dried fruits, juices, chewing tablets, freeze-dried powders, canned fruits, tablets etc.) and are sold mainly via online stores (websites). In the USA, some bars, restaurants and hotels have these fruits on their menus. According to the applicant, miraculin does not have a GRAS status given by the FDA since it is considered to be a food additive and no application has been submitted for its authorisation. Fruits can be cultivated and sold while falling under the remit of the USDA. Furthermore, the applicant has consulted with the US FDA adverse event reporting system (FAERS) public dashboard and did not find any entry related to miraculin or the raw material (fruits). In Japan, the fruits are considered as food and can be sold without restrictions, as stated by the applicant.

3.8. Uses and use levels and anticipated intake

3.8.1. Target population

The target population proposed by the applicant is the general adult population with the exception of pregnant and lactating women. The applicant proposed to exclude those subgroups of the population since there is insufficient information available for their safety assessment.

3.8.2. Proposed uses and use levels

The applicant proposed to use the NF as or in food supplements (in various forms such as capsules, powders, orally dissolving tablets, lozenges, liquids, chewing gums and gels) at a maximum dose of 0.9 g per day (divided over three servings).

3.9. Absorption, distribution, metabolism and excretion (ADME)

The applicant conducted an *in vitro* study to analyse the digestibility of a protein extract of the NF (miraculin) through incubation with different enzymes (Menéndez-Rey, 2018). The non-proteolytic enzymes (DNAse, RNAse, α -amylase, lactase) and proteolytic enzymes (pepsin, peptidase D, carboxypeptidase M, trypsin) were used to assess whether they can degrade miraculin under optimal (non-physiological) conditions. Miraculin remained stable after enzymatic treatment with non-proteolytic and some proteolytic enzymes (peptidase D and carboxypeptidase M) but was degraded after the treatment with pepsin and trypsin, which is in line with natural protein digestion in the GI tract, as stated by the authors.

3.10. Nutritional information

As previously mentioned in Section 3.4 *Compositional data*, relevant information on nutrient and antinutrient composition of the NF is available. Taking into account the maximum daily dose of the NF proposed by the applicant (i.e. 0.9 g/day), the Panel considers that the consumption of the NF is not nutritionally disadvantageous.

3.11. Toxicological information

The applicant provided several toxicological studies on the NF. These studies are listed in Table 10.

Table 10: Summary of toxicological studies with the NF

| Reference | Type of study | Test system | Dose |
|--|---|---|---|
| Study No. IF-74616 (CERETOX, 2018a) | Bacterial reverse mutation test (GLP, OECD TG 471) | <i>Salmonella</i> Typhimurium TA98, TA100, TA102, TA1535 and TA1537 | Up to 5,000 µg/plate (absence and presence of S9 mix) |
| Study No. 20229053 (Charles River, 2020a) | Bacterial reverse mutation test (GLP, OECD TG 471) | <i>S. Typhimurium</i> TA98, TA100, TA102, TA1535 and TA1537 | Up to 5,000 µg/plate (absence and presence of S9 mix) |
| Study No. IF-74516 (CERETOX, 2018b) | <i>In vivo</i> mammalian erythrocyte micronucleus test (GLP, OECD TG 474) | Wistar rats | 2,000 mg/kg bw/day (oral gavage) |
| Study code: 20/020-013C (Charles River, 2020b) | <i>In vitro</i> mammalian cell micronucleus test (GLP, OECD TG 487) | Mouse lymphoma L5178Y TK+/- 3.7.2C cells | Up to 1,000 µg/mL |
| Study No. IF-81517 (CERETOX, 2018c) | Acute oral toxicity study by Up-and-Down Procedure (GLP, OECD TG 425) | Wistar rats | 5,000 mg/kg bw per day |
| Study No. 73416 (CERETOX, 2018d) | 90-day repeated dose oral toxicity study with a 14-day recovery period (GLP, OECD TG 408, limit test) | Wistar rats | 2,000 mg/kg bw per day |

bw: body weight; CERETOX: Centre de Recerca en Toxicologia; GLP: Good Laboratory Practice; OECD Organisation for Economic Co-operation and Development

3.11.1. Genotoxicity

A bacterial reverse mutation test (CERETOX, 2018a) was performed according to OECD Test Guideline No 471 (OECD, 1997) and in compliance with the principles of Good Laboratory Practice (GLP). Using *Salmonella typhimurium* tester strains TA98, TA100, TA102, TA1535 and TA1537 and the plate preincubation method, the NF was tested in the main and confirmatory tests at dose levels up to 5.0 mg/plate (all strains), both in the absence and presence of a metabolic activation system, MAS (S9-mix). The Panel notes that no certificate of analysis for MAS has been provided. As a negative control (NC), sterile water was used and as positive controls (PC), sodium azide (without S9) and 2-aminoanthracene (2-AA) (with S9). According to OECD TG No. 471, 2-AA should not be used as the sole indicator of the efficacy of the S9-mix. The Panel notes that in the main and confirmatory tests, for strain TA102 (both with and without S9) the number of revertant colonies in NC was out of the range of historical control data (reaching almost 2-fold increase). Some colony counts in the confirmatory test were discarded, due to contamination. Furthermore, an increase of revertant colonies in the confirmatory test for strain TA1535, while not dose-dependent, reached significant increases of almost 2.5-fold in mid-dose groups in comparison to NC. However, in the main test, no significant increase was observed.

The Panel considered that an additional bacterial reverse mutation test, using a preincubation method with all strains or a mammalian system (OECD TG 476; OECD, 2016a) was needed for better assessment of the mutagenic potential of the NF.

Upon request, the applicant submitted an additional bacterial reverse mutation test (Charles River, 2020a). The study was performed in accordance with OECD TG No. 471 (OECD, 1997), EC Guideline No 440/2008⁷ and GLP. *S. typhimurium* tester strains TA98, TA100, TA102, TA1535 and TA1537 were exposed to the NF in two independent experiments, using a direct plate assay and a pre-incubation assay, both in the absence and presence of a MAS (S9-mix). Based on the dose-range finding study, the NF was tested up to 5 mg/plate. The NF did not induce a significant dose-related increase in the number of revertant colonies in any of the five tester strains, both in the absence and presence of the S9-mix.

An *in vivo* assessment of genotoxicity was also undertaken, using the rat erythrocyte (sampled from peripheral blood) micronucleus assay (CERETOX, 2018b). This test was conducted in accordance with OECD TG 474 (OECD, 2016b) and in compliance with GLP. The NF was administered twice (24 h apart) via oral gavage to 5 male Wistar rats in a dose of 2,000 mg/kg body weight (bw). Blood samples from the tail vein were obtained ~ 43 h after the treatment. At least 2,000 erythrocytes per animal were analysed, counting the number of polychromatic erythrocytes (PCE) and at least 4,000 erythrocytes for the proportion of micronuclei (MN)/PCE. No statistically significant increases in the number of cells with micronuclei were observed compared to the negative control (0.5% carboxymethylcellulose sodium salt, CMC).

The Panel considers that it is not known whether and to what extent the NF or its metabolites have reached the target cells. Thus, this study is not sufficient to properly address the genotoxic potential of this NF and the applicant was requested to perform an *in vitro* mammalian cell micronucleus assay (OECD TG 487; OECD, 2016c). This testing strategy is in line with the EFSA Scientific Committee recommendations of *in vitro* tests to be used as the first step in testing (EFSA Scientific Committee, 2011).

As requested, the applicant provided an *in vitro* mammalian cell micronucleus test (Charles River, 2020b), conducted in accordance to OECD TG 487 (OECD, 2016c) and in compliance with the principles of GLP. Mouse lymphoma L5178Y TK^{+/−} 3.7.2C cells were used as a test system. A 3-h treatment with S9-mix and 3-h and 24-h treatments without S9-mix were performed. Sampling was performed 24 h after the beginning of the treatment. The examined concentrations of the NF were 31.25, 62.5, 125, 250, 500 and 1,000 µg/mL. Since the positive control did not produce expected results in the short-term treatment with S9-mix (due to technical issues as presumed by the study authors), this test was repeated. The insolubility of the NF was observed in the final treatment medium at the end of the treatment at 500 and 1,000 µg/mL. No cytotoxicity was observed after any treatment. None of the treatment concentrations caused a biologically or statistically significant increase in the number of micronucleated cells when compared to the negative control values (vehicle; 0.5% CMC).

The Panel concludes that the provided studies do not raise concerns for the genotoxicity of the NF.

3.11.2. Acute toxicity

In an acute oral toxicity study in rats (CERETOX, 2018c), 3 female Wistar rats were administered the NF up to 5,000 mg/kg bw in a study design following an Up-and-Down procedure (UPD). The study was conducted in accordance with OECD TG 425 (OECD, 2008) and no adverse effects were recorded. The Panel considers that in general, acute toxicity studies are not pertinent for the safety assessment of NFs.

3.11.3. Subchronic toxicity

The applicant submitted results of a 90-day repeated dose toxicity study in male and female Wistar rats (CERETOX, 2018d), conducted in accordance with OECD TG 408 (limit test; OECD, 1998) and in compliance with GLP. Rats (10/sex per group) were randomised in the negative control group (0.5% CMC) and one dose group receiving the NF by oral gavage at a dose level of 2,000 mg/kg bw per day. Additional groups (5/sex per group) receiving 0 (control) or 2,000 mg/kg bw per day were included in order to assess the reversibility or progression of any test item-related changes after a 14-day recovery period. No systemic clinical signs, behavioural changes or mortality were observed at either control or treated group, as well as no effects on food and water intake. Furthermore, no test item-related effects in the treatment group were observed on bw and bw gain in comparison to the control.

⁷ COUNCIL REGULATION (EC) No 440/2008 of 30 May 2008 laying down test methods pursuant to Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Part B: Methods for the Determination of Toxicity and other health effects. Guideline B.13/14: "Mutagenicity: Reverse Mutation Test using Bacteria". OJ No. L 142, 31.05.2008. p. 248–256.

Some haematological, coagulation and clinical blood chemistry parameters, as well as organ weights, reached statistical significance, but did not show consistency between main and recovery groups, sex or trend over time or were of small magnitude and thus were considered as incidental (Annex A). The only relevant findings recorded at the histological examination were at the lung level. High incidence of foci of alveolar macrophages or foreign body granulomas was noted in control or treated rats, respectively. This is considered related to the experimental procedures (i.e. gavage administration) and to the characteristics of the test item that is a suspension at acidic pH.

Even though only one dose level is used in a limit test, the Panel considers that this study with 2,000 mg/kg bw does not raise concern in regard to sub-chronic toxicity of the NF.

3.11.4. Human data

The applicant submitted one sensory study with healthy young adults (Aguiló Aguayo and Echeverria Cortada, 2018) conducted with the NF and referred to several publications investigating the efficacy and sensory properties of *S. dulcificum* fruits in human subjects (Table 11).

In a sensory test (Aguiló Aguayo and Echeverria Cortada, 2018), nine healthy volunteers were recruited to evaluate the effect of different miraculin concentrations (up to 300 mg) over the time period of 60 min on the sweetness and sourness perception, using visual analogue scales. A solution consisting of sugars and acids was tasted after the NF was applied on the subject's tongue in form of chewable tablets and was left to dissolve for 2 min. The sweetness perception reached its peak in the first 5 min and was highly reduced at the end of the test period. The duration of the taste-altering effect (up to 120 mins) was in line with what has been reported elsewhere (Kurihara and Beidler, 1968; Igarashi et al., 2013; Rodrigues et al., 2016; Tafazoli et al., 2019). According to the applicant, none of the participants reported any adverse effects.

Other studies involving human subjects assessing the taste altering properties of different products derived from *S. dulcificum* fruits are summarised in Table 11.

Table 11: Overview table of human studies

| Reference | Study Design | Study Population | Duration of Study | Doses; route of administration |
|----------------------------|--------------------------------|--|---|--|
| Wong and Kern (2011) | Randomised, blinded cross-over | 13 females | 4 non-consecutive trial days within 2 weeks | Not available (freeze dried pill form); Supralingual |
| Igarashi et al. (2013) | Sensory evaluation experiment | 18 subjects (8 males and 10 females, around 20 years of age) | Single occasion | Not available (thawed freeze-dried miracle fruit); Buccal |
| Rodrigues et al. (2016) | Time-intensity test | 12 healthy adults | Single occasion (triplicates) | 300 mg of Frooties®; Supralingual |
| Capitanio et al. (2011) | Sensory evaluation experiment | 10 healthy adults (3 males and 7 females) | Three occasions | 25 mg of miraculin; Supralingual |
| Hudson et al. (2018) | Sensory evaluation experiment | 97 (1st experiment), 84 (2nd experiment) and 80 (3rd experiment) subjects | 2 non-consecutive days | 1 tablet (stated to be an equivalent of 1 miracle fruit berry); Buccal |
| Andrade et al. (2019) | Time-intensity test | 11 adults (8 women and 3 men) | 2 non-consecutive occasions | 150, 300 and 600 mg of spray-dried miracle fruit; Supralingual |
| Wilken and Satiroff (2012) | Non-randomised control trial | 8 participants on chemotherapy (4 in the treatment group and 4 in placebo) | 2 weeks | 6 Miracle Fruits™ per day. |
| Tafazoli et al. (2019) | Sensory study | 6 panellists | Single occasion | 0.08 g of miracle fruit powder; Supralingual |

The Panel notes that none of the available human studies investigated safety-related parameters of the NF or products of its source, but rather its taste-altering properties. While considering this and

other inherent limitations of these studies for their use in a safety assessment, the Panel notes that the authors did not report adverse effects regarding possible local effects (e.g. irritation of the tongue and/or mouth) at a maximum reported dose of 600 mg (Andrade et al., 2019) or duration of 2 weeks (Wilken and Satiroff, 2012).

Upon a request to provide more evidence on the safety of the NF in the context of chronic consumption in humans and possible prolonged or permanent taste alteration, the applicant submitted an expert opinion. The expert opinion concluded that data available from sensory studies suggest that the taste-altering effect of miraculin has a rapid onset and disappearance with no desensitising impact on the receptors.

The Panel notes a lack of data addressing to possible change in taste preference after long-term use.

3.12. Allergenicity

The total protein content of the NF is approx. 5-6% (w/w) and the glycoprotein miraculin represents about 15-40% of this amount. Glycoproteins are often allergenic (Woodfolk et al., 2015; Lei and Grammer, 2019). According to the applicant, no allergic reactions upon the consumption of fruits of *S. dulcificum* have been reported. Some species belonging to Sapotacea family are also known by their latex production (De Faria et al., 2017) and cross-reactivity between latex and fruit allergens (latex-fruit syndrome) has been described (Brehler et al., 1997).

Sequence homology has been carried out (Cózar, 2018) between the miraculin amino acid sequence (Uniprot. Id: P13087) and all the protein amino acid sequences of the National Center for Biotechnology Information (NCBI) database using protein BLAST analysis tool (Basic Local Alignment Search Tool) (Altschul et al., 1990). The results revealed that the sequences with higher homology to miraculin (> 50% sequence identity) were proteins from peach, sesame and bitter lemon (Kunitz trypsin inhibitor 2) and from tomato (miraculin precursor). In the same study, the sequential identity between miraculin and widely known protein allergens from other plants was assessed. At a cut off higher than 50%, sequence identities were detected with allergens from latex (83%), peach (50%) soy (53%) and peanut (80%) but with low query cover %. The author concludes that "no significant homology between miraculin and widely known pan-allergens has been found using BLAST". The Panel considers these results as preliminary and they do not allow to draw definitive conclusions on cross-reactivity.

A similar *in silico* evaluation using the allergen database 'Allergen Online'⁸ was performed to evaluate the potential allergenicity of miraculin (Tafazoli et al., 2019, 2020). An identity match higher than 35% over an 80 amino acid window was taken as a significant sequence homology and evidence for cross-reactivity. Significant alignments (\geq 35% identity) with seven proteins, including the Kunitz trypsin inhibitor 2 from soy and proteinase inhibitor and aspartic protease inhibitor from potato, were found. In the same study, miraculin was shown to be rapidly and completely digested under simulated physiological gastric conditions (pepsin).

The applicant also performed an internal preliminary enzyme-linked immunosorbent assay (ELISA) screening with the major food allergens. The results showed that the NF tested positive for peanut allergens.

By combining all these results, the Panel considers that cross-reactivity exists between the NF and peanut allergens as well as a potential cross-reactivity with latex, peach and soy allergens.

4. Discussion

The NF is pitted and lyophilised berries of *S. dulcificum* Daniell and contains glycoprotein miraculin (\leq 2.5%). The applicant proposes to use the NF as or in food supplements in various forms which will allow the delivery of miraculin into the mouth, for the general adult population (with the exception of pregnant and lactating women). The maximum daily amount of the NF to be consumed is 0.9 g, as proposed by the applicant.

The Panel considers that, taking into account the proposed conditions of use, the consumption of the NF is not nutritionally disadvantageous and the exposure to the contaminants present in the NF is not of toxicological relevance.

The only dose tested in the 90-day oral toxicity study of 2,000 mg/kg bw per day was not associated with adverse effects. As the proposed daily intake of the NF of 0.9 g/day, corresponding to 12.9 mg/kg

⁸ <http://www.allergenonline.org>

bw per day for an adult with default bw of 70 kg (EFSA Scientific Committee, 2011), the resulting margin of exposure (MOE) is 155. The Panel considers that the MOE of 200 (uncertainty factor 10×10 for inter- and intraspecies extrapolation and additional uncertainty factor 2 to account for lack of chronic toxicity data) is necessary to ensure the safety of the NF. Thus, the Panel derives a maximum intake level of 10 mg/kg bw per day for the NF, which corresponds to 0.7 g/day for an adult of 70 kg bw.

Regarding the specific proposed use of this NF (supralingual), the Panel considers that there was no irritation in the non-glandular (fore-stomach) epithelium from the submitted *in vivo* subchronic oral toxicity study, which would lead to concern regarding local effects in human tongue and mouth. Furthermore, no such effect was reported in the available sensory studies with human subjects or in the history of use of the source of the NF, as well as in the limited post-market surveillance data regarding the products similar to the NF (i.e. containing miraculin).

No studies reporting or investigating possible prolonged alterations in taste sensation following chronic consumption of the NF or of *S. dulcificum* fruits were identified. However, the history of consumption of miraculin and *S. dulcificum* fruits do not reveal an indication for permanent taste-alterations. Despite the uncertainties, the Panel is of the view that the likelihood of prolonged or permanent taste alterations is low, considering that the taste cells have regenerative capabilities with an approximate life span of 8–22 days (Beidler and Smallman, 1965; Perea-Martinez et al., 2013) and that the miraculin taste-altering effect is reversible and typically lasts between 30 and 120 min (Kurihara and Beidler, 1968; Igarashi et al., 2013; Rodrigues et al., 2016; Aguiló Aguayo and Echeverría Cortada, 2018).

5. Conclusion

The Panel concludes that the NF is safe for use as or in food supplements at the maximum intake level of 0.7 g/day for the target population, i.e. adults excluding pregnant and lactating women.

5.1. Protection of Proprietary data in accordance with Article 26 of Regulation (EU) 2015/2283

The Panel could not have reached the conclusion on the safety of the NF under the proposed conditions of use without the data claimed as proprietary by the applicant, i.e. compositional studies, and toxicological information (genotoxicity and sub-chronic toxicity studies).

6. Steps taken by EFSA

- 1) On 25/03/2019 EFSA received a letter from the European Commission with the request for a scientific opinion on the safety of dried fruits of *Synsepalum dulcificum* as a novel food. Ref. Ares(2019)2068055 – 25/03/2019.
- 2) On 26/03/2019, a valid application on the safety of dried fruits of *Synsepalum dulcificum* as a novel food, which was submitted by Baia Food Co. (Medicinal Gardens S.L.), was made available to EFSA by the European Commission through the Commission e-submission portal (NF 2018/0709) and the scientific evaluation procedure was initiated.
- 3) On 18/10/2019, EFSA requested the applicant to provide additional information to accompany the application and the scientific evaluation was suspended.
- 4) On 08/07/2020, additional information was provided by the applicant through the Commission e-submission portal.
- 5) On 22/07/2020 and 14/08/2020, EFSA requested the applicant to provide further clarifications to the additional information provided.
- 6) On 27/07/2020 and 17/03/2021, additional clarifications were provided by the applicant through the Commission e-submission portal and the scientific evaluation was restarted.
- 7) During its meeting on 27/04/2021, the NDA Panel, having evaluated the data, adopted a scientific opinion on the safety of dried fruits of *Synsepalum dulcificum* as a NF pursuant to Regulation (EU) 2015/2283.

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Abbreviations

| | |
|---------|--|
| AA | aminoanthracene |
| ADME | absorption, distribution, metabolism and excretion |
| BLAST | Basic Local Alignment Search Tool |
| bw | body weight |
| CERETOX | Centre de Recerca en Toxicologia |
| CFU | colony forming units |
| CMC | carboxymethylcellulose |
| DMB | dried miracle berries |
| DNAse | deoxyribonuclease |

| | |
|-----------|--|
| dw | dry weight |
| ELISA | enzyme-linked immunosorbent assay |
| FAERS | US FDA adverse event reporting system |
| FDA | Food and Drug Administration |
| FID | flame ionisation detector |
| GAE | Gallic acid equivalents |
| GC | gas chromatography |
| GI | gastrointestinal |
| GLP | Good Laboratory Practice |
| GRAS | generally recognized as safe |
| HACCP | Hazard Analysis Critical Control Points |
| HPLC | high-performance liquid chromatography |
| ICP | inductively Coupled Plasma |
| KTi | Kunitz trypsin inhibitor |
| LB | lower bound |
| LC-MS/MS | liquid chromatography with tandem mass spectrometry |
| LOQ | limit of quantification |
| MAS | metabolic activation system |
| MN | micronuclei |
| MOE | Margin of Exposure |
| MS | mass spectrometry |
| NC | negative control |
| NCBI | National Center for Biotechnology Information |
| NDA Panel | Panel on Nutrition, Novel Foods and Food Allergens |
| NF | Novel Food |
| OECD | Organisation for Economic Co-operation and Development |
| OES | optical emission spectrometry |
| PAHs | polycyclic aromatic hydrocarbons |
| PC | positive control |
| PCE | polychromatic erythrocytes |
| PCR | polymerase chain reaction |
| qH-NMR | quantitative ¹ H-nuclear magnetic resonance |
| RH | relative humidity |
| RNAse | ribonuclease |
| STI | soybean trypsin inhibitor |
| TIU | trypsin inhibitor unit |
| UFLC | ultra-fast liquid chromatography |
| UPD | up-and-down |
| USDA | United States Department of Agriculture |
| UV-VIS | ultraviolet-visible |
| w/w | weight per weight |

Annex A – Summary of the 90-day oral toxicity study (OECD TG 408, limit test)

| Study title | | 90-day oral toxicity study of a lyophilized novel food in Wistar rats with a 14-day recovery period (CERETOX, 2018d) | | | | | |
|--|-----|---|--------------------------------|---------------------------|--------------------------------|--------------|------------------|
| Tested system | | Wistar rats (RjHan:Wistar) | | | | | |
| Test material | | The novel food, batch #1. | | | | | |
| Dose/concentration (route of administration) | | Control group: 0 (vehicle: phosphate buffer solution of carboxymethylcellulose (CMC) sodium salt) 10 animals/sex Recovery control group: 5 animals/sex Dose group: 2,000 mg/kg bw/day (lyophilized powder of miracle berries (MBP) suspended in the vehicle) 10 animals/sex Recovery dose group: 5 animals/sex | | | | | |
| Method | | OECD TG 408 (limit test) | | | | | |
| Key results | | | | | | | |
| | | Dose groups (mean ± SD) | | | | | |
| Parameter (unit) | Sex | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (recovery) | 2,000 (recovery) |
| | | At day 45 | | At day 90 | | At day 105 | |
| Haematology | | | | | | | |
| RBC (x10 ¹² /L) | M | 7.53 (0.47) | 7.70 (0.69) | 7.97 (0.61) | 8.09 (0.22) | 7.42 (0.43) | 7.26 (1.38) |
| | | 7.93 (0.20) | 7.75 (0.32) | 8.54 (0.66) | 9.40 (0.31)* | | |
| | F | 7.45 (0.25) | 7.85 (0.49)* | 7.52 (0.24) | 7.77 (0.74) | 7.65 (0.76) | 7.84 (0.73) |
| | | 8.02 (0.71) | 8.41 (0.86) | 8.24 (0.42) | 7.80 (1.99) | | |
| MCV (fL) | M | 61.17 (2.02) | 58.97 (1.52)* | 56.83 (4.38) | 57.33 (2.89) | 55.34 (2.31) | 56.12 (2.08) |
| | | 58.85 (0.46) | 60.49 (0.87)** | 58.94 (1.13) | 58.93 (0.39) | | |
| | F | 62.95 (1.82) | 59.43 (4.91)* | 60.98 (3.15) | 57.92 (5.61) | 56.31 (8.56) | 50.79 (7.37) |
| | | 55.61 (7.96) | 53.52 (9.07) | 57.86 (9.39) | 56.13 (9.08) | | |
| MCH (g/L) | M | 19.35 (0.63) | 17.72 (2.83) | 18.38 (0.98) | 18.39 (0.63) | 18.08 (0.57) | 18.01 (1.29) |
| | | 18.76 (0.54) | 19.03 (0.25) | 18.37 (0.55) | 18.60 (0.56) | | |
| | F | 19.50 (0.59) | 18.69 (1.47)* | 19.06 (0.57) | 18.73 (1.63) | 18.06 (2.59) | 17.48 (2.34) |
| | | 17.85 (2.37) | 17.49 (2.68) | 17.79 (3.19) | 17.17 (2.40) | | |
| BNE (%) | M | 2.6 (2.3) | 0.3 (0.7)** | 1.5 (1.1) | 0.2 (0.4)** | 0.2 (0.4) | 0.2 (0.4) |
| | | 1.0 (1.4) | 0.6 (0.9) | 0.0 (0.0) | 0.0 (0.0) | | |
| | F | 0.5 (0.5) | 0.7 (1.1) | 0.7 (1.1) | 0.5 (0.7) | 0.2 (0.4) | 0.2 (0.4) |
| | | 0.6 (0.9) | 0.0 (0.0) | 0.4 (0.5) | 0.8 (0.8) | | |

| | | Dose groups (mean ± SD) | | | | | |
|--------------------------|-----|---------------------------|--------------------------------|---------------------------|--------------------------------|----------------|------------------|
| Parameter (unit) | Sex | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (recovery) | 2,000 (recovery) |
| | | At day 45 | | At day 90 | | At day 105 | |
| MCHC (g/L) | M | 316.44 (4.80) | 299.76 (43.46) | 324.30 (14.73) | 321.36 (16.86) | 327.38 (21.03) | 320.81 (16.70) |
| | | 318.70 (6.92) | 314.65 (4.08) | 311.73 (6.91) | 315.54 (7.68) | | |
| | F | 309.79 (7.94) | 314.66 (5.80) | 312.96 (8.40) | 323.79 (11.17)* | 321.69 (17.80) | 344.69 (13.25)* |
| | | 321.61 (10.15) | 327.72 (15.31) | 306.69 (6.32) | 306.98 (9.76) | | |
| MON (%) | M | 7.7 (2.9) | 9.6 (4.1) | 0.8 (0.9) | 0.1 (0.3)* | 4.2 (2.4) | 5.0 (3.0) |
| | | 7.4 (4.0) | 7.8 (2.8) | 2.0 (0.7) | 2.6 (1.7) | | |
| | F | 5.7 (2.1) | 5.7 (3.1) | 0.3 (0.9) | 0.0 (0.0) | 6.2 (3.0) | 5.0 (1.6) |
| | | 5.6 (1.1) | 5.6 (2.1) | 2.0 (1.6) | 3.0 (1.0) | | |
| EOS (%) | M | 1.3 (1.3) | 0.8 (1.3) | 1.1 (0.9) | 3.2 (1.6)** | 0.8 (1.3) | 0.8 (1.1) |
| | | 2.2 (2.5) | 1.6 (2.6) | 2.0 (2.0) | 0.4 (0.5) | | |
| | F | 0.6 (0.7) | 1.1 (2.5) | 1.7 (1.4) | 2.2 (2.0) | 0.4 (0.5) | 1.8 (1.9) |
| | | 0.8 (0.8) | 1.4 (0.5) | 0.6 (0.9) | 1.2 (0.8) | | |
| Coagulation parameters | | | | | | | |
| PT (sec) | M | 14.4 (0.8) | 15.7 (1.5)* | 14.8 (0.9) | 15.7 (0.9)* | 17.5 (5.1) | 13.4 (0.9)** |
| | | 15.0 (0.6) | 16.1 (1.5) | 26.5 (7.7) | 37.9 (12.4) | | |
| | F | 15.5 (1.3) | 16.0 (1.1) | 15.4 (1.3) | 15.9 (2.9) | 11.7 (0.3) | 12.5 (0.9) |
| | | – | 16.4 (1.4) | 36.6 (17.4) | 30.3 (9.0) | | |
| APTT (sec) | M | 47.0 (3.6) | 49.9 (4.0)* | 34.8 (9.1) | 41.9 (13.4) | 47.5 (25.6) | 34.1 (12.9) |
| | | 46.3 (13.1) | 48.5 (2.8) | 87.9 (–) | 51.8 (29.4) | | |
| | F | 62.2 (6.6) | 49.2 (4.5)* | 30.8 (6.1) | 45.5 (27.8) | 32.4 (6.6) | 33.2 (9.2) |
| | | 43.4 (2.9) | 47.8 (4.8) | 48.8 (10.5) | 82.6 (26.5)* | | |
| Clinical blood chemistry | | | | | | | |
| TRIGL (mg/dL) | M | 289 (67) | 292 (72) | 239 (101) | 183 (46) | 192 (83) | 231 (78) |
| | | 341 (66) | 266 (32) | 279 (93) | 287 (39) | | |
| | F | 168 (21) | 133 (43)* | 181 (60) | 190 (67) | 202 (76) | 231 (97) |
| | | 186 (89) | 156 (33) | 229 (56) | 234 (60) | | |

| Parameter (unit) | Sex | Dose groups (mean \pm SD) | | | | | |
|------------------|-----|-----------------------------|--------------------------------|---------------------------|--------------------------------|--------------|------------------|
| | | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (recovery) | 2,000 (recovery) |
| | | At day 45 | | At day 90 | | At day 105 | |
| AST/GOT (U/L) | M | 136 (31) | 184 (61)* | 188 (92) | 121 (34) | 155 (55) | 140 (28) |
| | | 132 (37) | 138 (14) | 180 (51) | 180 (23) | | |
| | F | 121 (25) | 105 (28) | 142 (51) | 104 (53) | 174 (73) | 125 (35) |
| | | 99 (17) | 111 (30) | 150 (17) | 126 (14) | | |
| CK (U/L) | M | 315 (106) | 705 (412)* | 1,113 (434) | 722 (322)* | 954 (234) | 999 (506) |
| | | 323 (146) | 482 (186) | 1,293 (352) | 1,654 (851) | | |
| | F | 379 (246) | 298 (112) | 930 (256) | 461 (183)** | 908 (599) | 599 (240) |
| | | 291 (124) | 266 (106) | 1,211 (142) | 832 (180)* | | |
| T-CHOL (mg/dL) | M | 173 (37) | 152 (37) | 147 (44) | 102 (20)* | 113 (27) | 97 (10) |
| | | 151 (29) | 124 (18) | 148 (37) | 109 (5) | | |
| | F | 122 (13) | 112 (13) | 107 (21) | 101 (25) | 100 (16) | 97 (16) |
| | | 107 (26) | 106 (20) | 127 (21) | 111 (17) | | |
| ALT/GPT (U/L) | M | 93 (31) | 110 (26) | 126 (70) | 75 (33) | 136 (40) | 134 (26) |
| | | 123 (45) | 71 (9)* | 89 (21) | 150 (28)** | | |
| | F | 61 (10) | 92 (38) | 109 (36) | 77 (28)* | 121 (36) | 122 (32) |
| | | 44 (14) | 99 (26)** | 134 (16) | 142 (12) | | |
| T-BIL (mg/dL) | M | 0.72 (14) | 0.67 (0.12) | 0.38 (0.15) | 0.24 (0.12)* | 0.44 (0.09) | 0.33 (0.10) |
| | | 0.64 (0.17) | 0.69 (0.08) | 0.81 (0.33) | 0.85 (0.18) | | |
| | F | 0.40 (0.13) | 0.41 (0.14) | 0.34 (0.12) | 0.18 (0.10)** | 0.52 (0.16) | 0.44 (0.16) |
| | | 0.43 (0.16) | 0.34 (0.19) | 0.66 (0.16) | 0.55 (0.23) | | |
| ALKP (U/L) | M | 419 (105) | 421 (116) | 249 (120) | 190 (45) | 206 (18) | 132 (18) |
| | | 454 (83) | 285 (38)** | 263 (18) | 215 (38)* | | |
| | F | 255 (38) | 216 (39)* | 139 (29) | 126 (27) | 169 (39) | 130 (18) |
| | | 198 (52) | 212 (47) | 177 (28) | 185 (45) | | |
| UREA (mg/dL) | M | 67 (20) | 67 (15) | 50 (12) | 40 (3)* | 37 (2) | 41 (2)** |
| | | 62 (13) | 49 (2) | 42 (2) | 43 (3) | | |
| | F | 42 (5) | 44 (4) | 40 (4) | 38 (5) | 44 (8) | 43 (3) |
| | | 48 (7) | 44 (2) | 41 (11) | 38 (3) | | |

| | | Dose groups (mean ± SD) | | | | | |
|---------------------------|-----|---------------------------|--------------------------------|---------------------------|--------------------------------|--------------|------------------|
| Parameter (unit) | Sex | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (control); 0 (recovery) | 2,000 (main); 2,000 (recovery) | 0 (recovery) | 2,000 (recovery) |
| | | At day 45 | | At day 90 | | At day 105 | |
| K (mmol/L) | M | 8.20 (0.46) | 8.51 (0.77) | 5.72 (1.21) | 4.81 (0.59)* | 5.55 (0.73) | 5.63 (0.19) |
| | | 7.56 (0.83) | 6.82 (0.12) | 5.84 (0.74) | 6.37 (0.23) | | |
| | F | 5.51 (0.44) | 5.46 (0.59) | 4.88 (0.58) | 4.50 (0.58)* | 5.31 (0.34) | 5.06 (0.36) |
| | | 5.73 (0.25) | 5.27 (0.69) | 6.03 (0.74) | 5.50 (0.26) | | |
| Ca (mmol/L) | M | 3.43 (0.50) | 3.46 (0.79) | 3.13 (1.01) | 2.51 (0.15) | 2.75 (0.11) | 2.78 (0.20) |
| | | 3.59 (0.20) | 2.96 (0.27)** | 2.56 (0.14) | 2.69 (0.14) | | |
| | F | 3.10 (0.22) | 2.47 (0.22)** | 2.79 (0.46) | 2.77 (0.27) | 2.94 (0.18) | 2.92 (0.19) |
| | | 2.36 (0.82) | 2.48 (0.27) | 2.78 (0.47) | 3.22 (0.30) | | |
| P (mmol/L) | M | 2.52 (0.28) | 2.38 (0.26) | 3.11 (0.98) | 2.40 (0.32)* | 3.11 (0.15) | 2.70 (0.30)* |
| | | 2.56 (0.28) | 2.28 (0.11) | 2.85 (0.32) | 2.49 (0.37) | | |
| | F | 2.04 (0.20) | 2.34 (0.23)** | 2.47 (0.46) | 2.29 (0.30) | 3.43 (0.08) | 2.98 (0.28)** |
| | | 2.25 (0.18) | 2.43 (0.17) | 2.51 (0.43) | 2.31 (0.29) | | |
| Organ weight (g) | | | | | | | |
| Liver | M | – | – | 19.8 (3.2) | 17.4 (2.5) | 19.1 (3.0) | 17.4 (2.0) |
| | F | – | – | 10.2 (0.5) | 8.0 (3.0)** | 9.5 (1.3) | 9.3 (1.1) |
| Spleen | M | – | – | 1.1 (0.1) | 0.9 (0.1)** | 1.0 (0.1) | 1.2 (0.1) |
| | F | – | – | 0.6 (0.2) | 0.6 (0.2) | 0.6 (0.1) | 0.7 (0.0) |
| Organ weight/bw ratio (%) | | | | | | | |
| Brain | M | – | – | 0.36 (0.03) | 0.40 (0.03)* | 0.34 (0.02) | 0.37 (0.02)* |
| | F | – | – | 0.62 (0.06) | 0.63 (0.03) | 0.64 (0.08) | 0.60 (0.05) |
| Liver | M | – | – | 3.72 (0.47) | 3.39 (0.37) | 3.44 (0.37) | 3.11 (0.29) |
| | F | – | – | 3.38 (0.21) | 2.99 (0.27)** | 3.06 (0.16) | 2.95 (0.09) |

RBC: erythrocyte count; MCV: mean corpuscular volume; MCH: mean corpuscular haemoglobin; BNE: band neutrophils; MCHC: mean corpuscular haemoglobin concentration; MON: monocytes; EOS: eosinophils; PT: prothrombin time; APTT: activated partial thromboplastin time; TRIGL: triglycerides; AST/GOT: aspartate aminotransferase; CK: creatine kinase; ALKP: alkaline phosphatase; T-CHOL: cholesterol, total; ALT/GPT: alanine aminotransferase; T-BIL: bilirubin, total.

*: Significantly different from control ($p < 0.05$).

**: Significantly different from control ($p < 0.01$).