**STable 1 The content of active ingredients from each bee products.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bee products** |  | **Biomacromolecule** | | | **Secondary metabolite** | | **Ref** |
| **Carbohydrates** | **Protein/peptides** | **Fats/ Fatty acids** | **Terpenes/carotenoids others** | **Polyphenols /flavonoids** |
| **Bee collection and brewing products** | BB  (Morocco) | Total free sugars (18 ± 1 g/100 g) | (19.96 ± 0.08 g/100 g) | Polyunsaturated  fatty acids  (64.7 ± 0.4%) |  |  | ([1](#_ENREF_1)) |
|  | BB  (Lithuania) |  |  |  |  | 196.3–221.6 mg RUE/100 g ;  78.8–156.7 mg RUE/100 g/ | ([2](#_ENREF_2)) |
|  | BB  (Portugal) | 58–78% | 14.1–21.8% | 3.6–16.8% |  |  | ([3](#_ENREF_3)) |
|  | BB  (not one kind) | (24–35%)  Monosaccharides 93.96%  Fructose (18.95%)  Glucose (11.54 %) | 21.93 and 22.12 % | 7.79 % |  |  | ([4](#_ENREF_4)) |
|  | BCP/BB  (Portuguese/  Japan) | 24–60 %-24–35% g | 20% protein | 3% Lipids |  |  | ([5](#_ENREF_5))  ([6](#_ENREF_6)) |
|  | BCP/BB  (Turkey) |  |  |  |  | 8.26 ± 0.29943.42 ± 0.779 mg GAE/g;  1.81 ± 0.040–4.44 ± 0.125 mg QE/g; | ([7](#_ENREF_7)) |
|  | BCP  (Lithuania) |  |  |  |  | 331.4–550.4 mg RUE/100 g ;  108.2–468.5 mg RUE/100 g | ([2](#_ENREF_2)) |
|  | Honey  (Germany &  Urbana) | Fructose (38%) and glucose (31%) |  |  |  |  | ([8](#_ENREF_8)) |
|  | BCP  (Białystok) | Carbohydrates (13–55%) are primarily fructose and glucose | Proteins and amino acids (10–40%) | Fats (1–20%) |  |  | ([9](#_ENREF_9)) |
|  | BCP  (Brazilian) | 68.10% and 75.51% | 19.44% and 23.80% | 2.66–7.34% |  |  | ([10](#_ENREF_10))  ([11](#_ENREF_11))  ([12](#_ENREF_12))  ([13](#_ENREF_13)) |
|  | BCP (Colombian) | Fructose (19.5 ± 0.9)  Glucose (13.6 ± 2.4)  Sucrose (6.7 ± 2.0) | 23.8 ± 3.2 g | 6.90 ± 3.5 g |  |  | ([13](#_ENREF_13)) |
|  | Honey  (Lithuania) |  |  |  |  | 2.95–10.18 mg RUE/10 g ;  0.28–5.22 mg RUE/10 g | ([2](#_ENREF_2)) |
|  | BCP  (Brazilian) | Glucose 8.77–19.12 %  Fructose14.45–20.23 % | 17.58–21.91% | 6.14–9.2 % |  |  | ([10](#_ENREF_10)) |
|  | BCP  (not mention) |  |  | 1–13 % |  |  | ([14](#_ENREF_14)) |
|  | BCP  (not mention) | 18.50–84.25%  reducing sugars 13–55% | Proteins and essential  amino acids (5–60%) | (0.15–31.26)% USF and SF |  | total phenolic content is  (0.69–213.20 mg GAE/g) | ([15](#_ENREF_15))  ([16](#_ENREF_16)) |
|  | BCP  (Scotland) | 13–55% | Protein and amino acids (10–40) % | Lipids (1–13) % |  |  | ([17](#_ENREF_17))  ([18](#_ENREF_18))  ([4](#_ENREF_4))  ([1](#_ENREF_1)) |
|  | Honey  (not mention) | 95–97% | 0.041% |  |  |  | ([19](#_ENREF_19))  ([20](#_ENREF_20)) |
|  | Honey  (not mention) | 82.4%  31% glucose, 38.5% fructose, 12.9% other sugars | 0.5% |  |  |  | ([21](#_ENREF_21))  ([22](#_ENREF_22)) |
|  | Honey  (not mention) | 82.40  Glucose 35.75, Fructose 40.94, Sucrose 0.89,  Maltose 1.44, Galactose 3.10 | 0.30 |  |  |  | ([23](#_ENREF_23)) |
|  | BCP  (Brazil) |  | 10.6–33.9 % | 3.2–8.3 % |  | 5.6–29.7 mg GAE/g  0.3–19.0 mg QE/g | ([24](#_ENREF_24)) |
|  | BCP  (Serbia) | 64.42–81.84% | 14.81–27.25% | 1.31–6.78% |  |  | ([12](#_ENREF_12)) |
|  | BCP  (not one kind) | 10–40% | 5–30% | 1–5% |  |  | ([25](#_ENREF_25)) |
|  | BCP  (not one kind) | 54.22% (18.50–84.25%) carbohydrates 13.41 % ;  (2.77–28.49 %) glucose;  15.36% (4.9–33.48 %) fructose;  4.25 % (0.05–9.02 %) sucrose | 21.30% (4.50–40.70%) | 5.31% (0.41–13.50%) Lipids |  | (0.69–213.20 mg GAE/g) | ([15](#_ENREF_15)) |
|  | BCP  (Brazil) | Reducing sugars (up to 46%) | Proteins (up to 31%) | Lipids (up to 13%) |  | Up to 1.5 % | ([26](#_ENREF_26)) |
|  | BCP  (Slovenia) | 13.2–27.8 % for fructose and 10.6–28.5 g %for glucose. |  |  |  |  | ([27](#_ENREF_27)) |
|  | BCP  (not one kind) | 40–85% (W/W) of dry bee pollen | 14–30% (W/W) | 1–10% (W/W) |  |  | ([28](#_ENREF_28)) |
|  | BCP  (Turkey) | 80.24 ± 0.836 | 15.69 ± 0.810 | 2.17 ± 0.038 |  | 14.42 ± 0.60 | ([29](#_ENREF_29)) |
|  | BCP  (Malaysia) | 57.06 ± 2.09–58.89 ± 0.28 | 21.70 ± 0.08–23.33 ± 0.48 | 4.64 ± 0.04–5.95 ± 0.10 |  |  | ([30](#_ENREF_30)) |
|  | BCP  (Ukraine) |  | 15.30 ± 2.09–28.06 ± 2.78 |  |  |  | ([31](#_ENREF_31)) |
|  | BCP  (Colombia) |  | 23.1 ± 2.9 g | 3.4 ± 1.1 g |  | 3.2 ±1.0 mg Quercetin/g  8.9 ± 3.1 mg Gallic acid/g | ([32](#_ENREF_32)) |
|  | BCP  (India) |  | 57036.67 ± 14.83 (mg/mL)  60780 ± 21.86 (mg/mL)  33953.33 ± 4.83 (mg/mL) |  |  | 0.91 ± 0.04 GAE/100 gm  0.99 ± 0.02 GAE/100 gm  0.80 ± 0.03 GAE/100 gm | ([33](#_ENREF_33)) |
|  | BCP  (European)  (England) | (130 mg/g ± 63) | 629 mg/g ± 290 wet weight | 38 ± 2 mg/g |  |  | ([34](#_ENREF_34)) |
|  | BCP  (Morocco) | (28.46% ± 0.994) | (12.81% ± 0.167) | (2.31% ± 0.574) |  | 14.88 ± 0.98 mg GAE/g  1.67 ± 0.12 mg QE  (quercetin equivalents)/g | ([35](#_ENREF_35)) |
|  | BCP  (Malaysia) | Fructose (17‒23%) glucose (14‒16%) and sucrose (5‒6%) | Colombian (24%) and Italian (22%)  Spanish sample (14%) | Spanish and Colombian (6%) Italian (2.5%) | Carotenoids 57, 25 and 221 µg/g for Spain, Italy, and Colombia BCP |  | ([36](#_ENREF_36)) |
|  | BCP  (Brazilian) | 54.9–82.8 % | 7.9–32.2 % | 3.2–13.5 % |  | (6.5–29.2 mg GAE/g)  (0.3–17.5 mg QE/g) | ([37](#_ENREF_37)) |
|  | BCP  (Korea) |  | 17.2 ± 0.18–26.8 ± 0.07% | 3.1 ± 0.10–12.2 ± 0.04% |  |  | ([38](#_ENREF_38)) |
|  | BCP | 90% of total sugars  Fructose and glucose  average contents ranged from 15.53–33.48 %  13.59–27.69 % |  |  |  |  | ([39](#_ENREF_39)) |
|  | BCP  (Turkey) |  |  | 3.37 ± 0.02%–6.85 ± 0.02% | 24.11 ± 0.09–98.62 ± 0.02 Carotenoid  content (mg/g) | TPC: 434.17 ± 0.01–719.58 ± 0.01 % | ([40](#_ENREF_40)) |
|  | BCP  (Greece) |  |  |  |  | 15.2 ± 0.4 to 60.2 ± 2.0 (mg GAE/g extract)  6.0 ± 0.3 to 57.6 ± 2.0 (mg QE/g extract) | ([41](#_ENREF_41)) |
|  | BCP  (Turkey) |  |  |  |  | 3.9 and 9.2 mg GAE/g-  1.2–1.9 mg CAE/g | ([42](#_ENREF_42)) |
|  | Honey  (Brazil)  BCP  (Brazil) | 215 ± 33–301 ± 169 (mg/g) | 45 ± 18–99 ± 9 (mg/g) | 2 ± 0–6 ± 1 (%) |  | 32 ± 9–136 ± 32 (mg GAEq/100 g);  8 ± 2–55 ± 20 (mg QEq/100 g)  6.9–21 ± 2 (mg GAEq/g);  0.3–17 ± 5 (mg QEq/g); | ([43](#_ENREF_43)) |
|  | BCP  (Brazil) |  |  |  |  | 33.73–75.60 mg GAE/g  1.42–9.05 mg QE/g | ([44](#_ENREF_44)) |
|  | Propolis |  |  |  |  | 13–379 mg of quercetin equivalents (QE) per g  68–500 mg of caffeic acid equivalents (CAE) per g | ([45](#_ENREF_45)) |
|  | Propolis  (Lithuania) |  |  |  |  | 68.03–99.85 mg RUE/10 g  /3.24–14.39 mg RUE/10 g | ([2](#_ENREF_2)) |
|  | BCP  (India) |  |  |  |  | 15.50 ± 1.25–25.63 ± 1.42 mg GAE/g and 9.72 ± 0.28–15.61 ± 0.74 mg RE/g | ([46](#_ENREF_46)) |
|  | Maize BCP  (Malaysia) | carbohydrates (44.30 ± 3.73) % | (17.16 ± 3.13) % | (0.62 ± 0.06%) |  | 783.02 mg GAE/ 100 g and 1706.83 mg QE/100 g | ([47](#_ENREF_47)) |
| **Bee secretions** | BV |  | Melittin 52% of all apitoxin peptides |  |  |  | ([9](#_ENREF_9)) |
|  | BV  (not mention) |  | 0.1 g mixture of peptides, enzymes, and nonpeptide components |  |  |  | ([48](#_ENREF_48)) |
|  | BV  (not one kind) |  | Small proteins and peptides |  |  |  | ([49](#_ENREF_49)) |
|  | Beeswax  (not mention) | MUD 1: 6.4 ± 1.0  MUD 2: 0.5 ± 2.3 | MUD 1: 12.9 ± 0.2  MUD 2: 2.3 ± 0.1 | MUD 1:11.0 ± 0.5  MUD 2:46.1 ± 3.7 |  | MUD 1: 1435.66  MUD 2: 432.66 mg GAE q/100 g | ([50](#_ENREF_50)) |
|  | RJ  (not one kind) | Near 30% | 27–41% | 8–19% |  |  | ([51](#_ENREF_51)) |
|  | RJ  (not one kind) | 10–16% (w/w) | 9–18% (w/w) |  |  |  | ([52](#_ENREF_52)) |
|  | RJ | (16%) | Proteins and amino acids (12.5%) | 5% |  |  | ([53](#_ENREF_53)) |
|  | RJ  (Japan) | 15% | 18% | 3–6% |  |  | ([21](#_ENREF_21))  ([54](#_ENREF_54)) |
|  | RJ  (not one kind) | 7–18% w/w | 9–18% w/w | 3–8% w/w |  |  | ([55](#_ENREF_55))  ([56](#_ENREF_56)) |
|  | RJ  (Lithuania) |  |  |  |  | 16.44–23.14 mg RUE/10 g/  10.34–17.19 mg RUE/10 g | ([2](#_ENREF_2)) |
|  | RJ  (not one kind) | 7.5–16% |  |  | Wax (5–6) %;  steroids (3–4) %;  phospholipids (0.4–0.8) % | Phenolic acids (4–10) % | ([57](#_ENREF_57)) |
|  | RJ  (not one kind) |  |  | 7–18% |  |  | ([58](#_ENREF_58))  ([59](#_ENREF_59)) |
| **Bee ecological bodies and hives** | Bee pupae  (Scotland) | (20.34%)  total sugar (0.73%) | (46.21%) | (26.09%) |  |  | ([17](#_ENREF_17)) |
|  | Honeybee larvae  (Japan) |  |  |  |  | 51.44 ± 2.77 total phenolic content (mg GAE/g)  2.47 ± 0.23 TFC (mg RE/g) | ([60](#_ENREF_60)) |
|  | Honeybee larva  (Japan) | 30.3% | 50.1% | 13.5% |  |  | ([61](#_ENREF_61)) |
|  | Larvae  (Korea) | 46.1±1.73 | 35.3±2.09 | 14.5±0.15 |  |  | ([62](#_ENREF_62)) |
|  | Pupae  (Korea) | 34.3±0.24 | 45.9±0.63 | 16.0±0.24 |  |  |  |

**Footnotes: BB**=Bee Bread; **BCP**=Bee Collected Pollen; **BV**= Bee Venom; **RJ**=Royal Jelly; **RUE**= rutin equivalent; **GAE**= Gallic Acid Equivalents; **QE**= Quercetin Equivalents; **RE**= Rutin Equivalents; **TFC**= Total Flavonoid Content; **TPC**= Total Phenolic Content; **CAE**=Caffeic Acid Equivalents;

**STable 2 The characteristics of each drying method.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Bee products** | **Drying technology** | **Conditions and achieve** | **Models and parameters** | **Advantages and disadvantages** | **Ref** |
| BCP  (Turkey) | Hot air chamber | * the highest sensory scores obtained at 40 °C * at 45, 50, 55, and 60 °C retained better quality | - | * A shorter processing time * Lower risk of microbial contamination * More effective * Better control * Applied in many industrial drying applications | ([63](#_ENREF_63)) |
| BCP  (Colombia.) | Solar drying | * The average temperature was 50 °C * air-flow speed of 2 m/s | - | * Generates energy savings Reduce the carbon footprint of the process | ([64](#_ENREF_64)) |
| BCP  (Colombia) | Hot air drying | * The most adequate temperature was at 60 °C * A marked increase in flavonoids, phenolics, and antioxidant activity * A loss of carotenoids Structure slight degradation | - | * modify the microstructure of the exine * Nutritional compounds would be more available | ([65](#_ENREF_65)) |
| BCP  (Russian) | Cyclic convective drying | * The rational circulation speed range 2.2–2.5 m/s; * air temperature 40–42 °C |  | * preserve the biologically active properties | ([66](#_ENREF_66)) |
| BCP  (Italy) | Freeze-drying (FD)  (using a lyophilizer Heto PowerDry  LL1500) | * condensation chamber temperature was −115 °C, * full vacuum. * treated for 270, 420, or 540 min, |  |  | ([67](#_ENREF_67)) |
| RJ  (Viet Nam) | FD | * optimal temperature was 20.58 °C, * optimal pressure was 0.411 mmHg * freeze time was 18.283 h * final product reached the minimum 6.32 kWh/kg, * The residual water content 4.19% under 4.5% (< 4.5%); * Loss of protein, carbohydrate, lipid, mineral salts, 10-HAD, vitamin B5, free fatty acids, * viscosity reached the minimum | * Using quadratic orthogonal experimental planning method |  | ([68](#_ENREF_68)) |
| RJ  (Italy) | FD | * At −50 °C for 24 h * Furoins content was higher in the freeze-dried RJ after both 6 and 12 months |  | * maintains the natural characteristics without damage or denature the thermolabile components | ([69](#_ENREF_69)) |
| RJ  (Viet Nam) | FD | * The optimal temperature of the FD chamber was 24.35 °C * The optimal pressure was 0.368 mmHg * The optimal time of the FD process was 19.225 h * After FD 3.51 under 4.5%, with the minimum value of the loss of nutrition | * Mathematical model of the residual water content * Mathematical model of the total protein loss * Mathematical model of the carbohydrate loss * Mathematical model of the loss of lipid | - | ([70](#_ENREF_70)) |
| BCP  (Turkey) | Infrared radiation drying | * Sample treated at different power levels 50, 62, 74, and 88 W. * surface morphological changes * quality characteristics retained better at 50 W | - | * Decrease the drying time * with high-quality * high energy efficiency * uniform temperature in the dried product | ([71](#_ENREF_71)) |
| BCP  (Italy) | FD and microwave-assisted drying (MWD) | * condensation chamber temperature was −115 °C * At full vacuum. * FD treatment for 9 h, * The residual water content was 6.0%, * The absolute pressure was 50 mbar. * 150 W MW treatment for 30 min |  |  | ([72](#_ENREF_72)) |
| BCP  (Brazil) | Infrared heating-assisted fluidized bed dryer | * Conventional drying at 35, 45, and 55 °C * velocity equal to minimum fluidization velocity * radiation intensity at 100, 400, and 700 W/m2 without heating the air * 52% energy saving achieve using the IR heating-assisted fluidized bed dryer. | * Moisture diffusion model   XR: moisture ratio;   * Kinetics of color | * Prevents browning reactions * Avoids color degradation | ([73](#_ENREF_73)) |
| BB  (Russia) | Convection drying method, |  |  | * High energy intensity of the process | ([74](#_ENREF_74)) |
| BB  (Russia) | Vacuum method, |  |  | * High cost of equipment | ([74](#_ENREF_74)) |
| BB  (Russia) | convective and infrared drying |  | COMSOL Multiphysics software   * model of drying a porous body | * Reduce the processing drying time and energy intensity | ([74](#_ENREF_74)) |
| BCP  (Turkey) | MWD | * 300, 450, 600, and 900 W power * 900 W created considerable degradation, nearly 26–28%, of vitamin E |  |  | ([29](#_ENREF_29)) |
| BCP  (Italy) | MWD | * 50 mbar; MW power was 150 W; the exposure time was 30 min * The residual water content was 6.4%, 10.3%, and 8.2% (chestnut, willow, and ivy pollen) |  | * Minimum affect the content of the flavonoids, complex B vitamins, and/or unsaturated lipids | ([75](#_ENREF_75)) |
| BCP  (Turkey) | Microwave-assisted vacuum drying (MW-VD) | * 300, 450, 600, and 900 W power |  | * Higher reduction in antioxidant compounds (tocopherols) * No substantial change in total phenols and flavonoid content of fresh bee pollen | ([29](#_ENREF_29)) |
| BCP  (Turkey) | Hot-air drying (HAD) | * Air velocity of 0.54 m/s * provided the best preservation of vitamin C at 35 °C * An average loss ranging between 12.9 and 29.2% in vitamin E content |  | * Vitamin E, beta-carotene, and vitamin C loses during the heating | ([29](#_ENREF_29)) |
| BCP  (Turkey) | Vacuum drying (VD) | * 300, 500 mbar |  |  | ([29](#_ENREF_29)) |
| BCP  (Turkey) | FD | * Vacuum pressure of 0.1 mbar * Vitamin E, total phenolic content, and TEAC values were similar |  | * The nutrition did not alter after FD | ([29](#_ENREF_29)) |
| BCP  (Italy) | FD | * The temperature in the condensation chamber was −115 °C, * full vacuum * The residual water content was 6.0%, 6.3%, and 7.5%(chestnut, willow, and ivy pollen) |  | * minimum affect the content of the flavonoids, complex B vitamins, and/or unsaturated lipids | ([75](#_ENREF_75)) |
| BCP  (Turkey) | low temperature high velocity (LTHV)-assisted fluidized bed  drying | * 4, 10, 24, and 40 °C, ~40–50 humidity (%) and 6 m/s air velocity * The cooling and heating unit was controlled with a thermostatic sensor connected | * Logarithmic (Logarithmic (asymptotic) | * Applied in the food industry * preserve the quality of the perishable and semi-dried food product at low temperature * minimize the lipid oxidation, * minimize the texture, color, protein, and sensory quality lost | ([76](#_ENREF_76)) |
| BCP  (Turkey) | Microwave drying | * 180, 360, 540, 720, and 900 W microwave power * Drying time was shortened by 94% when increased from 180 to 900 W | * The moisture contents of the BCP   Arrhenius type equation | * Microwave energy speeds up the drying process * energy saving, and drying with smaller dryer sizes * Shorten drying time, * retain nutritional value * improve the final quality of dried products | ([77](#_ENREF_77)) |
| BCP  (Turkey) | Hot-air (HAD) and vacuum (VD) | * (300, 500 mbar) drying at 35, 50 and 65 °C, * A higher retention of enzyme activity, was observed at 50 °C |  |  | ([78](#_ENREF_78)) |
| BCP  (Italy) | Classic hot air drying (HAD) | * A temperature of 32 °C for 24 h in the NTW100 cool-air dryer * Residual water was 7%, |  | * produce Maillard’s compounds after drying | ([75](#_ENREF_75)) |
| BCP  (Turkey) | MWD and microwave-assisted vacuum drying (MW-VD) | * (500, 675 mbar) at 300, 450, 600, and 900 W power * A greater reduction was observed in DN of samples at 600 and 900 W * Proline and HMF content were affected by the treatment power |  |  | ([78](#_ENREF_78)) |
| BCP  (Turkey) | FD |  |  | * preserve the bioactive compounds and biological properties | ([78](#_ENREF_78)) |
| BCP  (Italy) | MW-VD | * 50 mbar for some minutes |  | * Reduces the water content without thermally deteriorating important bioactive compounds | ([79](#_ENREF_79)) |

**Footnotes: BCP**=Bee Collected Pollen; **BB**=Bee Bread; **RJ**= Royal Jelly; **FD**=Freeze-drying; **HAD**=Hot-air drying; **MW-VD**=Microwave-assisted Vacuum Drying; **VD**=Vacuum Drying; **LTHV**=Low Temperature High Velocity; **MWD**=Microwave-assisted Drying; **TEAC**= Trolox Equivalent Antioxidant Capacity; **HMF**=Hydroxymethylfurfural; **10-HAD**=10-hydroxy-decenouc acid; **IR**= Infrared

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