PIPERONYL BUTOXIDE (062)

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EXPLANATION

Piperonyl butoxide was evaluated by the 2001 JMPR. Further discussion at the present Meeting resulted in some changes to the recommendations. The appraisal below replaces the 2001 appraisal and should be read in conjunction with the 2001 monograph.

APPRAISAL

Piperonyl butoxide {5-[2-(-butoxyethoxy)ethoxymethyl]-6-propyl-1,3-benzodioxole} is a synergist used to prolong the effects of insecticides. The compound was reviewed by the 1992 JMPR for both residues and toxicology. Some critical data on the metabolism in plants and animals studies were not submitted. Furthermore, the studies of stability and processing that were received were related only to commercially stored wheat and wheat products. Therefore, withdrawal of all the MRLs was recommended. At its Twenty-sixth Session (1994), the CCPR decided to withdraw the CXLs for cereal grains and for all other commodities (ALINORM 95/24), except for wheat, which was advanced to step 5/8. The 1995 JMPR established an ADI of 0–0.2 mg/kg bw.

At its twenty-ninth session, the CCPR scheduled piperonyl butoxide for periodic review at the 1999 JMPR, but at its thirtieth session it re-scheduled the review for 2000 (ALINORM 99/24 App.VII). The compound was reviewed by the 2001 JMPR Meeting within the CCPR periodic review programme. At this Meeting, further clarification allowed refinement of the evaluation.

The Meeting received information from the manufacturer on physical and chemical properties, metabolism and environmental fate, analytical methods, stability in freezer storage, registered uses, the results of supervised trials on pre- and post-harvest uses, studies of processing, studies of animal transfer, residues in food in commerce and national residue limits. The Australian Government provided information on registered uses and national residue limits.

Animals metabolism

Three studies were conducted on metabolism in rats. In the first study, rats were dosed with [^{14}C]piperonyl butoxide labelled in the glycol side-chain at a single dose of 50 or 500 mg/kg bw or repeated doses of 50 mg/kg bw per day. Seven days after treatment, 27–38% of the radiolabel had been excreted in urine, 55–66% in faeces and 0.89–1.5% in carcass and tissues, with no specific trends by sex or dose. The highest concentration of residue was found in the gastrointestinal tract (up to 2.0 mg/kg). Piperonyl butoxide was detected only in urine from female rats dosed with 50 mg/kg bw, and eight metabolites were identified (representing 0.8–6.7% of the administered dose). Piperonyl butoxide can be metabolized at the propyl side-chain, the glycolate side-chain and the dioxole ring. A product of cyclization of the propyl and glycolate chain (lactone of 6-hydroxymethyl-1,3-benzodioxol-5-ylacetic acid) was the main compound in male rat urine (5.2–6.8%). In faeces, piperonyl butoxide accounted for 2.2–31% of the administered dose. Of the four metabolites detected, 4-{[2-(2-butoxyethoxy)ethoxy]methyl}-5-propyl-1,2-benzenediol, a catechol with an intact glycolate chain, was the main one, representing 9.4–26% of the administered dose.

In a second study, formulated [^{14}C]piperonyl butoxide applied to discs of skin excised from rats showed a potential for absorption through skin. After 24 h, 31% of the radiolabel was recovered in the skin homogenate. In a third study, rats received a single dose of ring-labelled piperonyl

butoxide at a dose of 50 or 500 mg/kg bw. Most of the radiolabel was eliminated within the first 48 h after dosing, primarily in the faeces. During the 7 days of collection, 11–23% of the administered dose was found in urine and 70–85% in faeces, with a mean of 97% in the excreta of animals at the high dose and 98% in the excreta of those at the low dose. The carcass accounted for 0.28–0.44% of the administered dose. The metabolite profiles in excreta were similar at the two doses, piperonyl butoxide being metabolized at the dioxole ring to produce either a catechol or a substituted anisole moiety, and at the glycolate side-chain. At the glycolate side-chain, metabolism occurred by hydroxylation at the terminal carbon, oxidation to acid, followed by successive losses of the acetate moiety to form alcohols and acids. At least 15 metabolites were identified in excreta of both male and female rats, the main metabolite being 4-{[2-(2-butoxyethoxy)ethoxy]methyl}-5-propyl-1,2-benzenediol, representing 19% of the administered dose.

One goat received a dermal application of a 10% solution of [^{14}C]piperonyl butoxide uniformly labelled in the benzene ring for 5 days, and two other goats were given feed containing 10 or 100 ppm for 5 days. The radiolabel was excreted rapidly by the orally dosed goats and more slowly by the dermally dosed goat. Within 22 h after administration of the last dose, most of the dose had been excreted in urine (73% and 79% after oral and 44% after dermal administration) and faeces (22% and 22% after oral and 8.9% after dermal administration). The amounts excreted in milk were similar throughout the study, with all dose regimens: 0.33% of the applied dose was found in milk of orally dosed goats and 0.53% in milk of the dermally dosed goat. Little radiolabel was found in muscle, and radiolabel was concentrated in the fat of dermally dosed animal (0.20 mg/kg) and in the liver of the orally dosed animals (0.36 and 2.0 mg/kg at the low and high doses, respectively). The same metabolite profiles were found in tissues and urine. Piperonyl butoxide was detected at > 0.02 mg/kg only in liver and fat from the animals given the high oral dose (0.12 and 0.13 mg/kg) and in fat from the dermally treated animal (0.16 mg/kg). It was metabolized primarily at the glycolate side-chain. Two metabolites were detected in milk, at concentrations of 0.001–0.016 mg/kg, which had a carboxylic acid moiety at C-2 or C-4 of the glycolate chain (4-(6-propyl-1,3-benzodioxol-5-yl)-2-oxabutanoic acid and 2-{2-[(6-propyl-1,3-benzodioxol-5-yl)methoxy]ethoxy}acetic acid). In kidney, the metabolites were found at concentrations of 0.001–0.045 mg/kg, and the alcohol precursor of the carboxylic acid at C-4 (2-{2-[(6-propyl-1,3-benzodioxol-5-yl)methoxy]ethoxy}ethanol) was detected. In liver, a catechol of the latter metabolite (4-{[2-(2-hydroxyethoxy)ethoxy]methyl}-5-propyl-1,2-benzenediol) was detected at 0.14 mg/kg.

In two studies, laying hens received [^{14}C]piperonyl butoxide uniformly labelled in the benzene ring for 5 consecutive days by dermal application at a dose of 14 mg/g under a sealed container 2.5 x 5 x 1.3 cm or in the feed at 10 or 100 ppm. Excreta from hens dosed dermally contained 59% of the applied radiolabel, and those from the hens dosed orally at the low and high doses contained 89% and 94%, respectively. In eggs, the concentration of radiolabel was higher in the white during the first 48 h (up to 0.63 mg/kg) and then concentrated in the yolk (up to 1.9 mg/kg at the higher oral dose). In tissues, the least radiolabel was found in muscle (0.002–0.124 mg/k) and the most in fat (0.13–4.8 mg/kg). The concentrations in kidney and liver were 0.11–1.6 mg/kg. At the end of the study, piperonyl butoxide was found in eggs and tissues at 0.006–1.2 mg/kg (the latter in egg yolk from hens given the high oral dose), but not in liver or kidney from hens given the low oral dose. No metabolites were found in egg white or fat. Of the four metabolites found in egg yolk, liver, kidney and thigh muscle, (6-propyl-1,3-benzodioxol-5-yl)methoxyacetic acid, 2-{2-[(6-propyl-1,3-benzodioxol-5-yl)methoxy]ethoxy}ethanol, 2-{2-[(6-propyl-1,3-benzodioxol-5-yl)methoxy]ethoxy}acetic acid and 4-{[2-(2-hydroxyethoxy)ethoxy]methyl}-5-propyl-1,2-benzenediol), the penultimate predominated, reaching 0.19 mg/kg in kidney from animals at the high oral dose.

Thus, in animals, piperonyl butoxide can be metabolized at the glycolate side-chain, through hydroxylation at the terminal carbon, oxidation to acid, followed by successive losses of the acetate moiety to form alcohols and acids, which can be conjugated; at the propyl side-chain, through cyclization with the hydrolysed glycolate chain; and through opening of the dioxole ring. The main residue in animal tissues, egg and milk is piperonyl butoxide.

Plants metabolism

The behaviour of [^{14}C]piperonyl butoxide labelled in the glycolate chain was studied after foliar application to cotton, potato and lettuce, leaf at the maximum rate of 0.56 kg ai/ha. Only minimal uptake or translocation of parent or degradates occurred in cotton and potato. The concentration of TRR found in potato tubers was 0.076% of that found in the leaves (617 mg/kg) 8 days after the fourth and last application. Cotton leaves collected 5 weeks after the fifth application had 142 mg/kg of total radiolabel. Hulls, lint and seed from cotton bolls collected 16 days after the sixth and last application contained 5, 0.4 and 0.3% of the radiolabel found in leaves. Piperonyl butoxide was not detected in potato tubers. The concentrations in cotton products ranged from 0.047 in lint to 1.23 mg/kg TRR in hulls, corresponding to 0.2–5% of that found in leaves (26.3 mg/g). In lettuce leaves, piperonyl butoxide was responsible for 51% of TRR on the day of the fifth application, but the percentage dropped to 24.4% after 10 days.

The aqueous fraction of the lettuce extract at day 0 (24.2% of TRR) contained at least three conjugated metabolites, two of which were identified, and a small amount of piperonyl butoxide (1.5% TRR). An aqueous extract from plants on day 10 contained five identified metabolites at concentrations of 0.2–2.0 mg/kg (0.9–7.6% TRR), consisting of conjugated alcohols formed after hydrolysis and truncation of the glycosate side-chain, with an intact dioxole ring.

Potato leaves contained at least seven degradates of high to moderate polarity, none of which represented more than 3% TRR. About 82% of the TRR was extracted into organic solvent, and more than 30 degradates were present, each at < 0.02 mg/kg (4% TRR). The metabolite profile was different in potato leaves and tubers. The degradation products in post-extraction solids of potato tubers were characterized as highly polar materials, probably the products of oxidation of one or both side-chains to benzyl alcohols or carboxylic acids and of opening of the dioxole ring to a catechol structure.

Cotton leaves contained 11 or more degradation products soluble in organic solvents; the predominant one (7.5% TRR) was similar to compounds found in lettuce, with one to three oxygen atoms remaining in the glycolate side-chain. The metabolites observed in the leaves were not observed in hulls, seeds or lint. In cotton seed, parent piperonyl butoxide was the only residue soluble in organic solvents. Mild acid hydrolysis of the post-extraction solids released almost 50% of the TRR, which presented two minor peaks (< 0.05 mg/kg) on the HPLC and a third, comprising 45% TRR (0.12 mg/kg), with characteristics similar to those in potato tubers. Cotton lint extract also contained a highly polar material that eluted at the HPLC solvent front (80% TRR, 0.19 mg/kg), which may have been the same dioxole ring-opened metabolite found in potato tubers and cotton seed, except that it was not bound. Cotton hulls contained five degradation products soluble in organic solvents (0.1% TRR). The predominant degradation products released by mild acid hydrolysis of the post-extraction solids was (6-propyl-1,3-benzodioxol-5-yl)methoxyacetic acid (5.1% TRR).

Thus, piperonyl butoxide is metabolized in plants in a manner similar to that in animals, except that more polar metabolites are formed, which are fully degraded molecules resulting from hydrolysis of the glycolate side-chain, oxidation of the propyl side-chain and opening of the dioxole ring. The main residue found in lettuce, potato and cotton leaves was piperonyl butoxide, and minimal translocation occurred to potato tubers and cotton products.

Environmental fate

Soil

A 2-mm layer of a sandy loam soil treated with [phenyl ring-^{14}C]piperonyl butoxide at a rate equivalent to 10 kg ai/ha was exposed to artificial sunlight for 15 days (corresponding to 41 days of natural sunlight) or kept in the dark. The half-life in both soils was 1–3 days. Four degradation

products were identified, resulting from loss of the glycolate side-chain and oxidation of the resulting benzyl alcohol to the corresponding aldehyde and acid. The concentration of hydroxymethyldihydrosafrole, a benzyl alcohol, reached a peak at day 3 (63 and 44% of the applied radiolabel in unirradiated and irradiated soil, respectively) and fell to 1.9 and 3.1% after 15 days. Hydroxymethyldihydrosafrole was oxidized to an acid (6-propyl-,3-benzodioxole-5-carboxylic acid) which accumulated in unexposed soil after 15 days (49% of applied radiolabel). More decomposition and oxidation of the phenyl ring, observed as formation of CO_2, occurred in irradiated soil (28%) than in the control dark soil (1.3%). In another experiment, piperonyl butoxide incubated in the dark for 242 days was degraded with a half-life of approximately 14 days, in a pathway similar to that discussed above. Two additional metabolites with oxidized propyl side-chains were detected at 0.1–8.9% of the applied radiolabel during the incubation period. More than one-half the applied piperonyl butoxide had been mineralized to CO_2 by 242 days.

Terrestrial dissipation of piperonyl butoxide was studied in soil treated at rate of 5.2 kg ai/ha in the USA. The half-lives were 4.3 days in California and Georgia and 3.5 days in Michigan. At 15 cm depth, the concentration of piperonyl butoxide after 14 days was 0.11–0.22 mg/kg and fell to < 0.10 mg/kg after 30 days of application. No parent compound was detected at any site in soil collected at depths below 15 cm.

Water–sediment systems

A solution of 1 mg/l radiolabelled piperonyl butoxide was stable when incubated at 25 °C in the dark for 30 days at pH 5, 7 or 9 in sterile aqueous buffers (97–100 % of the applied radiolabel recovered). In another experiment, a 10 mg/l solution of [^{14}C]piperonyl butoxide (at pH 7) exposed to natural sunlight for 84 h degraded with a half-life of 8.4 h. Two main photoproducts were observed: hydroxymethyldihydrosafrole (22% and 48% of the applied radiolabel after 4 and 84 h, respectively) and its aldehyde oxidation product (3,4-methylenedioxy-6-propylbenzaldehyde; 5.7–11% of the applied radiolabel). At least five other minor degradation products were found, each representing < 10% of the applied radiolabel. Unexposed samples contained up to 2% of radiolabel associated with metabolites.

Radiolabelled piperonyl butoxide in a sandy loam soil water–sediment system incubated under aerobic conditions in the dark (10 mg/kg sediment or 3.2 μg/ml of water) degraded slowly, and 72% of the piperonyl butoxide remained after 30 days. Under anaerobic conditions, 91% of the parent compound was still present after 181 days. In both systems, it degraded to hydroxymethyldihydrosafrole and further to 3,4-methylenedioxy-6-propylbenzaldehyde and acid, which represented up to 3.8% of the applied radiolabel.

The adsorption and desorption characteristics of piperonyl butoxide radiolabelled in the phenyl ring were assessed in sand, clay loam, sandy loam and silt loam soils at a concentration of 0.4, 2, 3 or 4 mg/l. The systems were equilibrated for 24 h at 25 °C in darkness at a soil:solution ratio of 1:10. Piperonyl butoxide showed low to moderate mobility in sandy loam, clay loam and silt loam (K_a, 8.4, 12 and 30, respectively) and high mobility in sandy soil (K_a, 0.98). The K_{oc} values ranged from 399 in sandy loam to 830 in silt loam. A K_d value was not determined for sandy soil, but in the other soils it ranged from 8.2 to 42 after the first desorption step and from 6.3 to 95 after the second.

The leaching behavior of [^{14}C]piperonyl butoxide was investigated in sand, silt loam, sandy loam and clay loam soils after application at a rate equivalent to 5 kg ai/ha to the top of 30-cm columns (1 mg/column) and eluted with 0.01 mol/L calcium chloride. Piperonyl butoxide did not leach readily into loam soils (0.2–1.3% of the applied radiolabel in the leachate), but it was highly mobile in sandy soil (74% in the leachate), with a distribution coefficient of 0.42 ml/g. When the experiment was conducted with a sandy loam soil aged for 18 days and treated with [^{14}C]piperonyl butoxide, 33% of the applied radiolabel remained in the top of the column (up to 5 cm) and 14% was recovered in the leachate. The three degradation products found (hydroxymethyldihydrosafrole, 3,4-methylenedioxy-6-propylbenzaldehyde and the acid) were more mobile than the parent compound,

being detected at 20–25 cm of the column. An extract of the aged soil contained 45% of the applied radiolabel as piperonyl butoxide.

Methods of analysis

One method for determining residues of piperonyl butoxide and its metabolites in raw and processed plant commodities involves extraction with acetonitrile, partition of piperonyl butoxide into petroleum ether and analysis by HPLC with fluorescence detection. The more polar metabolites remain in the aqueous phase, which is subjected to mild acid hydrolysis to convert the metabolites quantitatively to hydroxymethyldihydrosafrole, which is extracted and also analysed by HPLC with fluorescence detection. The LOQ for piperonyl butoxide and for total metabolites was 0.10 mg/kg, with an average recovery of 91–94%. In grapes and cranberries, < 70% of metabolites were recovered. In another method, the extract containing piperonyl butoxide was brominated and cleaned up by liquid–solid partition, and the eluate was analyzed by GC with ECD. The LOQ for piperonyl butoxide was 0.10 mg/kg, and average recovery was 56% in beans to 67% in peanuts. Other solvents can be used to extract piperonyl butoxide from wheat and the milled fraction, including methanol, hexane and ethyl acetate.

In the method used to determine residues of piperonyl butoxide in milk, eggs and tissues, samples were extracted with acetonitrile, the fat was removed with hexane, sodium chloride added, and piperonyl butoxide partitioned into hexane. The hexane solution was cleaned up on a silica gel solid-phase extraction column, and piperonyl butoxide was determined by GC–MS. The LOQ was validated at 0.05 mg/kg for tissues (liver, kidney, muscle and fat), with recovery of 70–108%. The recovery at 0.01 and 0.05 mg/kg from milk was 67–120%, and that from eggs was 71–104%.

Stability of residues in stored analytical samples

Piperonyl butoxide at 1.0 mg/kg was stable in samples stored frozen in the dark for up to 12 months. In potato tubers and chips, leaf lettuce, broccoli, cucumber, grapes, orange fruit, molasses, juice and dry pulp, tomato fruit, juice, puree, dry and wet pomace, succulent beans pod and vine, cotton seed, oil and soapstock and beans, 70–108% of the added piperonyl butoxide remained after a 12-month storage. In potato granules, potato wet peel and cotton meal, these values varied from 53 to 68%. When piperonyl butoxide was added to sweets, meat, bread, sugar and peanuts at a concentration of 0.2 mg/kg, 50–69% remained after 12 months of frozen storage.

Definition of the residue

On the day of application, piperonyl butoxide accounted for 51% of the TRR in lettuce, two metabolites being formed in approximately equal amounts and accounting for 24% of the radiolabel. After 10 days, the concentration of piperonyl butoxide had decreased by half, and at least 10 metabolites were formed, each representing < 10% of the TRR. Piperonyl butoxide was not translocated to potato tubers or cotton products when applied to the leaves of these plants. Some highly polar material was found in cotton seed and in lint, representing 44 and 80% TRR, respectively. Although these metabolites were not identified, they were highly degraded compounds and, owing to their high polarity, would probably not accumulate in animals if ingested. Although no studies of metabolism in stored plant commodities were conducted, the Meeting agreed that piperonyl butoxide is degraded mainly by photolysis and considered that such studies were not necessary, as the residues are very stable in cereal grains in storage. No major metabolite was found in edible animal commodities. The main compound in both plant and animal commodities is piperonyl butoxide.

The Meeting agreed that the residue definition for compliance with MRLs and for estimating dietary intake in plant and animal commodities should continue to be piperonyl butoxide.

Piperonyl butoxide has a log P_{ow} of 4.6 and is concentrated in the fat of animals dosed orally and dermally. The Meeting concluded that piperonyl butoxide is fat-soluble.

Results of supervised trials

Pre-harvest trials were conducted in crops in various regions of the USA between 1992 and 1996, with 10–12 applications of pyrethrins containing piperonyl butoxide, according to maximum GAP for piperonyl butoxide (0.56 kg/ha; no PHI).

Citrus. Seven supervised trials were conducted on citrus. The concentrations of residues of piperonyl butoxide in lemon were 3.1 and 1.7 mg/kg, those in oranges were 0.90, 0.98 and 1.0 mg/kg and those in grapefruit were 0.49 and 1.4 mg/kg. The concentrations in citrus were, in ranked order (median underlined): 0.49, 0.90, 0.98, 1.0, 1.4, 1.7 and 3.1 mg/kg. Although there were fewer trials on citrus fruits than would be required for a major crop, piperonyl butoxide is used to only a minor extent as a synergist in pre-harvest treatment in pyrethrin formulations. Recommendations for pyrethrins in citrus were made by the 2000 JMPR on the basis of trials conducted with a pyrethrin–piperonyl butoxide formulation. Therefore, the Meeting agreed to recommend an MRL of 5 mg/kg and an STMR of 1.0 mg/kg for piperonyl butoxide in citrus.

Berries and small fruits.Seven supervised trials were conducted on berries and small fruits. The concentrations of residues of piperonyl butoxide were 2.8 mg/kg in blackberry, 5.0 and 5.5 mg/kg in blueberry, 4.2 mg/kg in cranberry, 9.6 mg/kg in grapes and 3.0 and 3.1 in strawberry. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in berries, strawberry and grapes. There is no current recommendation for pyrethrins in berries and small fruits.

Brassica vegetables. Three supervised trials were conducted on broccoli, giving rise to concentrations of residues of piperonyl butoxide of 0.69, 1.7 and 2.3 mg/kg. In three trials conducted on cabbage, the concentrations were 0.09, 0.23 and 0.46 mg/kg, while those in cabbage with wrapper leaves were 1.1, 6.4 and 2.7 mg/kg. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in broccoli and cabbage. There is no current recommendation for pyrethrins in broccoli and cabbage.

Curcubits. Eight supervised trials were conducted on curcubits. The concentrations of residues of piperonyl butoxide were 0.83 and 0.61 mg/kg in cantaloupe, 0.07 and 0.68 mg/kg in cucumber and 0.10, 0.20, 0.25 and 0.27 mg/kg in squash. The Meeting agreed that the data on residues in curcubits could be combined as 0.07, 0.10, 0.20, 0.25, 0.27, 0.61, 0.68 and 0.83 mg/kg, and estimated a maximum residue level of 1 mg/kg and an STMR of 0.26 mg/kg for piperonyl butoxide in curcurbits.

Peppers and tomato.In three supervised trials conducted on peppers, the concentrations of residues of piperonyl butoxide were 0.39, 0.59 and 1.4 mg/kg. In three trials conducted in tomato, the values were 0.37, 0.76 and 1.0 mg/kg. Although there were fewer trials on peppers and tomato than required for these crops, the Meeting agreed to consider the data sufficient to recommend maximum residue levels, for the reasons outlined for citrus fruits. The data for peppers and tomato were combined, in ranked order, as 0.37, 0.39, 0.59, 0.76, 1.0 and 1.4 mg/kg. The Meeting estimated a maximum residue level of 2 mg/kg and an STMR of 0.675 mg/kg for piperonyl butoxide in peppers and tomato.

Leafy vegetables.Nine supervised trials were conducted on leafy vegetables. In head lettuce the concentrations of residues of piperonyl butoxide were 0.54 and 0.35 mg/kg ; when the wrapper leaves were attached, the values were 5.0 and 3.6 mg/kg. Leaf lettuce contained concentrations of 19 and 23 mg/kg, mustard greens contained 37 and 38 mg/kg, radish leaves (crowns with leaves) contained 38 mg/kg and spinach contained 32 and 39 mg/kg. The concentrations in mustard greens, radish leaves and spinach are within the same range and provide mutual support. They were, in ranked order: 32, 37, 38 (2) and 39 mg/kg. The Meeting recommended a maximum residue level of 50 mg/kg and an STMR of 38 mg/kg for piperonyl butoxide in mustard greens, radish leaves, leaf lettuce and spinach.

Legume vegetables.Two supervised trials were conducted on succulent beans, giving concentrations of piperonyl butoxide in pods of 0.34 and 2.2 mg/kg: In two trials conducted in succulent peas, the values were 2.2 and 5.1 mg/kg. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in succulent beans and peas.

Root and tuber vegetables. In one supervised trial conducted on carrot, the concentration of residues of piperonyl butoxide in roots was 1.1 mg/kg. Three trials conducted on potato gave values in tubers of < 0.10 (2) and 0.11 mg/kg, one trial on radish gave a value in roots of 0.34 mg/kg and two trials conducted on sugar beet gave concentrations in roots of < 0.10 mg/kg. In a study of metabolism conducted with labelled piperonyl butoxide on potato at maximum GAP, no residues were detected in tubers. Although there were fewer trials on root and tuber vegetables than would be required for this group, the Meeting agreed to consider the data sufficient to recommend residue levels, for the reasons outlined for citrus fruits. As only one trial was conducted on carrots, giving a much higher value than for the other commodities in the group, the Meeting agreed to combine the values for all commodities except carrots. Those are, in ranked order: < 0.10 (3), 0.11 and 0.34 mg/kg. The Meeting estimated a maximum residue level of 0.5 mg/kg and an STMR of 0.10 mg/kg for piperonyl butoxide in root and tuber vegetables, except carrots.

Pulses. In two supervised field trials on dry beans and two on dry peas at GAP rate, the concentrations of piperonyl butoxide residues in seed were 0.10 and 0.11 mg/kg in beans and 0.27 and 0.57 mg/kg in peas. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not to recommend a maximum residue level for piperonyl butoxide in pulses due to pre-harvest use.

Celery. In two supervised trials on celery, the concentrations of residues of piperonyl butoxide were 17 and 23 mg/kg in untrimmed leaf stalk and 0.98 and 2.3 mg/kg in the petiole. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in celery.

Mustard seed. One supervised trial was conducted on mustard seed, which gave a concentration of piperonyl butoxide residues of 2.1 mg/kg. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in mustard seed.

Cotton seed.In five supervised trials conducted on cotton seed, the concentrations of residues of piperonyl butoxide were < 0.10 (2), 0.10 (2) and 0.21 mg/kg. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in cotton seed. There is no current recommendation for pyrethrins in cotton seed.

Animal feed. In four trials conducted on succulent or dry beans, the concentrations of residues in vine were 16 (2), 26 and 28 mg/kg. In hay samples dried for 2–6 days in the open air, the values were 11, 14, 21 and 42 mg/kg, and those in forage were 14 and 25 mg/kg. In four trials on succulent or dry pea, the concentrations in vine were 26, 29, 47 and 96 mg/kg. In hay samples dried for up to 14 days in the field or in a greenhouse, the values were 3.7, 38, 48 and 153 mg/kg, and those in forage were 31 and 42 mg/kg.

The Meeting agreed that the data on residues in bean vines represent the same population as those for pea vines and could be used to support a recommendation for pea vines. The concentrations were, in ranked order: 16 (2), 26 (2), 28, 29, 47 and 96 mg/kg. When the median (27 mg/kg) and the maximum values (96 mg/kg) were corrected for moisture content (75%, *FAO Manual*, p. 125), the values were 108 mg/kg and 384 mg/kg, respectively, in dry matter. The Meeting recommended a maximum residue level of 400 mg/kg and an STMR of 108 mg/kg for piperonyl butoxide in pea vines, green (dry basis).

The Meeting agreed that the data on residues in bean and pea hay represented a single population and could be combined, in ranked order, as 3.7, 11, 14, 21, 38, 42, 48 and 153 mg/kg. The median (29.5 mg/kg) and the maximum (153 mg/kg) values were corrected for the moisture content of pea hay (12%, *FAO Manual*, p. 125), and became 19.9 and 174 mg/kg, respectively, on a dried basis. The Meeting estimated a maximum residue level of 200 mg/kg and an STMR of 19.9 mg/kg for piperonyl butoxide in bean hay and pea hay or fodder.

As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in pea and bean forage.

In five supervised trials conducted on cotton forage, the concentrations of residues of piperonyl butoxide were 20, 28, 30 (2) and 37 mg/kg. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in cotton forage.

In two trials conducted with sugar beet leaf, the concentrations of residues of piperonyl butoxide in crowns with leaves attached were 37 and 12 mg/kg. As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not recommend a maximum residue level for piperonyl butoxide in sugar beet leaves.

Post-harvest treatment

Trials were conducted in which navy beans in cloth bags underwent treatment with up to 10 applications of piperonyl butoxide at the label rate in a warehouse by a space spray (0.25 kg ai/1000 m^3) and a contact spray (0.3 kg ai/100 m^2). One bag was collected for analysis after each application, for a total of 10 bags from each treatment. The concentrations of residues were < 0.05 (2) (LOD), < 0.10 (3) (LOQ), 0.10, 0.13 (2), 0.16 and 0.17 mg/kg in samples collected after the space spray treatment and < 0.05 (10) mg/kg in samples after the contact spray treatment. The concentrations of residues after post-harvest use were, in ranked order, < 0.05 (12), < 0.10 (3), 0.10, 0.13 (2), 0.16 and 0.17 mg/kg.

The Meeting estimated a maximum residue level of 0.2 mg/kg, an STMR value of 0.05 and a highest residue of 0.17 mg/kg for piperonyl butoxide in pulses after post-harvest use.

Trials were conducted with harvested peanuts in cloth bags treated in a warehouse with 10 applications at the label rate by a space spray (0.25 kg ai/1000 m^3) and a contact spray (0.3 kg ai/100 m^2). One bag was collected for analysis after each application, for a total of 10 bags from each treatment. The concentrations of residues in samples collected after each space spray treatment were < 0.10 (3), 0.20, 0.24, 0.28, 0.29, 0.36 and 0.54 (2) mg/kg, while those after contact spray treatment were < 0.05 (6) and < 0.10 (4) mg/kg. The concentrations after post-harvest use were, in ranked order: < 0.05 (6), ≤ 0.10 (7), 0.20, 0.24, 0.28, 0.29, 0.36 and 0.54 (2) mg/kg.

The Meeting estimated a maximum residue level of 1 mg/kg and an STMR value of 0.10 mg/kg for piperonyl butoxide in peanuts after post-harvest treatment.

Trials were conducted with prunes treated in a warehouse with 10 applications at the label rate by a space spray (0.25 kg ai/1000 m^3) or a contact spray (0.3 kg ai/100 m^2). One bag was collected for analysis after each application, for a total of 10 bags from each treatment. The concentrations of residues in samples collected after each space spray treatment were < 0.05 (5), < 0.10 (4) and 0.11 mg/kg, while those after contact spray were < 0.05 (6) and < 0.10 (4) mg/kg. The concentrations of residues after post-harvest use were, in ranked order, ≤ 0.05 (11), < 0.10 (8) and 0.11 mg/kg.

The Meeting agreed that the values for residues in prunes could be extended, and estimated a maximum residue level of 0.2 mg/kg and an STMR value of 0.05 mg/kg for piperonyl butoxide in dried fruits after post-harvest treatment.

Post-harvest trials were conducted on cacao beans, raisins and wheat flour in Germany during 1993–94 with eight space spray applications of pyrethrum–piperonyl butoxide formulation containing piperonyl butoxide at 21.3 g/1000 m^3 at 14-day intervals, or two applications of piperonyl butoxide at 128 g/1000 m^3. Samples were taken on days 0, 14, 30, 60 and 90 after treatment. In Germany, GAP for space spray treatment of stored products consists of 0.375–132 g ai/1000 m^3.

Two trials were conducted on cacao beans in jute sacks. At the lower rate, the concentrations of residues in beans 0 and 14 days after the last application were 0.21 and 0.25 mg/kg and then fell to 0.08 mg/kg at day 90. At the higher rate, the concentrations varied from 0.52 mg/kg on day 0 to 0.75 mg/kg on day 30. In one trial conducted at the higher rate (128 g ai/1000 m^3) on raisins in stored polythene and cardboard, the concentration was < 0.01 mg/kg at all sampling times. In one trial on wheat flour at the same rate, the concentrations ranged from 0.12 mg/kg at day 14 to 0.46 mg/kg at day 60.

As insufficient data from trials performed according to GAP were submitted, the Meeting agreed not to recommend a maximum residue level for piperonyl butoxide in cacao beans or wheat flour after post-harvest treatment. The maximum residue level, STMR value and highest residue for raisins are covered by the recommendations for dried fruits after post-harvest treatment.

Two trials were conducted on wheat in Germany. The concentrations in grain after the lower rate of treatment (21.3 g/1000 m^3) varied from 0.71 mg/kg after 30 days to 2.5 mg/kg on day 0. Samples taken after the higher rate of treatment (128 g/1000 m^3) contained concentrations of 1.3 mg/kg on day 30 and 2.2 mg/kg on day 0.

In the USA, there are two further approved post-harvest uses for piperonyl butoxide as a pyrethrin formulation on stored grains: direct treatment of grain as it is carried to a silo (11.1–26 mg a.i./kg of grain) or application to grain in storage (0.12–0.24 kg ai/100 m^2). A series of trials was conducted in the USA in 1959 with various formulations of piperonyl butoxide applied to wheat at various rates as it was transferred to the bins. Up to five bins were treated at each application rate, and samples were taken 3–25 months after application. In three trials conducted at maximum GAP, the highest concentrations of piperonyl butoxide residues in all bins were 12, 17 and 25 mg/kg. One trial at lower rate gave similar results (maximum, 12 mg/kg), and the highest value in one trial conducted at a rate below GAP was 5.2 mg/kg.

Although trials were conducted on wheat in the USA according to GAP in 1959–61, full reports were not provided. The concentrations of piperonyl butoxide residues during storage for up to 12 months ranged from 4.1 to 13 mg/kg.

In Australia, piperonyl butoxide can be used on grain in various insecticide formulations for post-harvest treatment at a rate of 2.4–8.5 mg ai/kg of grain. In a series of trials conducted in 1978–79, treated wheat was sampled after up to 9 months of storage. In nine trials conducted at maximum GAP, the highest concentrations during sampling were 3.4, 8.0, 7.1, 7.2, 6.2, 9.1, 7.5 (2) and 8.0 mg/kg. In 10 trials conducted at a lower GAP rate or at a higher rate, the concentrations ranged from 2.4 to 16 mg/kg.

In 31 trials conducted in Australia in 1981–82, wheat treated with piperonyl butoxide at 10 mg/kg of grain in various formulations was sampled up to 9 months after treatment. The highest concentrations of residues found were 5.7 (2), 7.9 (3), 4.2 (2), 7.3 (3), 5.3, 5.0, 7.0 (2), 4.5, 7.8 (2), 5.2, 4.8, 7.5, 8.1, 8.2, 10 (3), 8.6, 9.2, 11, 8.0, 9.4 and 30 mg/kg. In four further trials conducted under the same conditions, treated wheat was sampled after 10–31 months of storage. The highest concentrations during this period were 7.3, 6.7 and 5.9 (2) mg/kg.

In a series of 13 trials conducted in Australia in 1979–80, wheat grain treated with various piperonyl butoxide formulations at 10 mg ai/kg of grain were sampled after up to 9 months of storage. The highest concentrations were 9.7 (2), 8.6, 7.7, 8.7, 8.9, 9.3, 9.5, 10 (2), 7.3, 8.4 and 14 mg/kg. In two other trials conducted at lower GAP the concentrations were 4.5 and 2.3 mg/kg.

In three trials conducted in Australia in 1998 at 8 mg ai/kg of grain in various formulations, the highest concentrations of piperonyl butoxide residues found during a 9-month storage period were 13, 16 and 5.4 mg/kg. In a trial conducted at a lower GAP, the concentration was 1.7 mg/kg. Although another 27 trials were conducted between 1990 and 1998, at rates of 4–10.7 mg ai/kg of grain, full reports of the studies were not provided. The highest concentrations found in each trial ranged from 1.5 to 8.9 mg/kg.

In Italy, piperonyl butoxide can be used after harvest in various formulations at a rate of 2.3–12.5 mg ai/kg of grain. In 18 trials conducted at various locations in Italy at a rate of 2.5, 5.0 or 10 mg/kg, samples were taken after up to 12 months of storage. The concentrations of residues in the trial at the highest GAP rate were 13, 3.9, 5.2, 4.2, 3.9 and 4.5 mg/kg. The highest concentrations in trials conducted at lower rates were 0.34–8.7 mg/kg.

Six post-harvest trials were conducted on barley in Australia in 1992–96 according to maximum GAP (6.33–8 mg ai/kg of grain) in three formulations. The grain was stored for up to 6.5 months. The highest concentrations of piperonyl butoxide residues were, in ranked order, 0.9, 6.0, 6.4, 6.5, 6.6 and 7.2 mg/kg. One trial at a lower rate gave values within the same range, but a full report of the study was not provided.

In 30 trials on maize in the USA conducted in 1952–57 with dust and spray formulation at rates of 10.4–29.4 mg ai/kg of grain, samples were taken after 1–50 months of storage. The highest concentrations of piperonyl butoxide found during storage in samples from the 10 trials conducted according to maximum GAP were 12, 11, 4.0, 8.0, 7.0, 8.0, 25, 6.0, 9.0 and 13 mg/kg, while those in trials conducted at lower GAP rates were 1–21 mg/kg. In another study, for which a full report was not provided, conducted at maximum GAP, the highest concentration found during 12 months of storage was 10 mg/kg.

Trials were conducted on maize with three concentrations of piperonyl butoxide applied by surface spray (49.7–149 g ai/m^2) at various frequencies of application. Three months after treatment, 25–41% of the total applied remained in the maize; after 6 months, this value had dropped to 11–13%.

In Italy, two trials were conducted on maize at the lowest and highest GAP rates, and samples were taken for analysis after up to 6 months of storage. The highest concentrations of piperonyl butoxide found were 1.3 mg/kg at the lowest GAP rate and 4.1 mg/kg at the highest rate.

In two trials conducted on sorghum in Australia at maximum GAP, the concentrations of piperonyl butoxide residues on day 0 were 2.9 and 10 mg/kg; these were reduced after 3 months of storage. Two trials at lower and higher rates gave highest values of 0.50 and 20 mg/kg. In another trial conducted at maximum GAP, the highest concentration found during a 6-month storage period was 9.7 mg/kg. A full report of this trial was not provided.

GAP for post-harvest use of piperonyl butoxide on cereal grains is 10 mg/kg of grain in Australia, up to 12.5 mg/kg of grain in Italy and up to 26 mg/kg of grain in the USA. The Meeting agreed that the estimates should be derived from the critical GAP, that of the USA. The concentrations of residues in trials conducted according to GAP in the USA (10 trials on wheat, three on maize) were, in ranked order: 4.0, 6.0, 7.0, 8.0 (2), 11, 12 (2), 8.0, 9.0, 13 and 25 mg/kg. The Meeting estimated a maximum residue level of 30 mg/kg and an STMR value of 11 mg/kg for piperonyl butoxide in cereal grains after post-harvest treatment.

Fate of residues during processing

A series of studies was conducted on processing of orange, grapes, tomato, beans, potato, sugar beets and cotton that had been treated with at least 10 applications at five times the GAP rate. Samples were collected on the day of the last application, except for cotton, samples of which were collected after 14 days. Bulk samples were processed into the required products by procedures that simulated commercial practice.

Three orange plots were treated and one bulk sample consisting of one-third of each treated plot was processed. The concentration of piperonyl butoxide residues in orange was 9.4 mg/kg. The residues concentrated in orange dry pulp and orange oil, with processing factors of 5.7 and 15. In orange molasses, the concentration of residues was reduced by a processing factor of 0.53, and no residue was found in orange juice (processing factor, < 0.01). On the basis of the recommended MRL of 5 mg/kg and the STMR value of 1.0 mg/kg in citrus fruits, the Meeting estimated an STMR-P value of 5.7 mg/kg in dried citrus pulp and a maximum residue level of 0.05 mg/kg and an STMR-P value of 0.01 mg/kg in citrus juice.

Three tomato plots were treated, and one bulk sample consisting of one-third of each treated plot was processed. The concentration of residues in tomato was 8.5 mg/kg, and was found in wet and dry pomace, with processing factors of 5.9 and 34, respectively. The concentrations of residues in tomato purée and juice were reduced, with processing factors of 0.33 and 0.15, respectively. On the basis of the recommended maximum residue level of 2 mg/kg and the STMR value of 0.675 mg/kg in tomato, the Meeting estimated a maximum residue level of 0.3 mg/kg and an STMR-P value of 0.10 mg/kg for tomato juice and an STMR-P of 0.22 mg/kg for tomato purée.

Three grape plots were treated, and samples were collected for processing. The concentrations of residues in fruit were 14 (2) and 11 mg/kg. In all samples, the concentration increased in raisin, raisin waste and wet and dry grape pomace, giving average processing factors of 1.1, 2.3, 2.1 and 5.5, respectively. The concentration in juice decreased to 0.22–0.24 mg/kg, giving a processing factor of 0.02. As no STMR value was recommended for grapes, the Meeting could not estimate an STMR-P value for grape products.

Samples from three treated potato plots contained no detectable residues (< 0.10 mg/kg), and no residues were found in granules or chips. The residues were concentrated in wet potato peel, giving an average processing factor > 1.5. On the basis of the STMR value of 0.10 mg/kg recommended for root and tuber vegetables, the Meeting estimated an STMR-P value for wet potato peel of 0.15 mg/kg.

The concentration of residues in sugar beet root in one treated plot was 0.08 mg/kg. The concentration increased after processing to dry pulp, with a processing factor of 3.6. No residues were detected in sugar or molasses (< 0.10 mg/kg), giving an estimated processing factor for both commodities of < 1.2.

In one treated plot of succulent bean, the concentration of residues in pods was 8.0 mg/kg. The residues concentrated in cannery waste, with a processing factor of 6.4.

Three treated cotton plots had concentrations of residues in seed of 0.10 mg/kg (3). Each sample was processed, and the residues were found mainly in hulls with an average processing factor of 1.1, in crude oil with an average processing factor of 6.2, in refined oil with an average processing factor of 20 and in soapstock with an average processing factor of 3.8. Residues were not detected in cotton meal (<0.10 mg/kg). As no STMR value was recommended for cotton, the Meeting could not estimate an STMR-P value for cotton products.

Various studies were conducted on processing of wheat at various locations. In three studies conducted in Australia, wheat treated with piperonyl butoxide at 8.0 mg ai/kg of grain was processed to bread and bran. The concentrations of residues in grain were 16 and 14 (2) mg/kg and residues

were found mainly in bran, giving processing factors of 4.45, 3.1 and 4.1 (average, 3.9); the values were reduced in bread, with processing factors of 0.023, ≤0.005 (no residues detected) and 0.06 (average 0.029). No information on the processing or analytical method was provided.

In a series of 12 studies in Australia, wheat was treated at a 15 mg ai/kg of grain, stored for 3 months and processed to bran and flour. The concentration of residues decreased after cleaning in flour, shorts and low-grade middling, with average processing factors of 0.82, 0.42, 0.56 and 0.50 respectively. In bran, the concentration increased, with an average processing factor of 1.7. A full report of the studies was not provided.

Eighteen processing studies were conducted in Italy with wheat treated at various rates and stored for 45 or 180 days. The processing factors of cleaned and decorticated grain ranged from 0.09 to > 1.8 (average 0.535) and from < 0.15 to 1.33 (average, 0.44), respectively. On average, the concentrations of residues in bran increased, with an average processing factor of 1.3 (< 0.02–3.1). In all studies, the concentrations of residues in flour decreased, with an average processing factor of 0.19, ranging from < 0.02 to 0.62.

Five hundred and forty tonnes of wheat treated with two formulations containing piperonyl butoxide were milled at intervals during storage for nine months. Residues were increased in bran and pollard with mean processing factors of 3.1 and 1.7, and decreased in meal, flour, whole meal bread and white bread by mean factors of 0.85, 0.19, 0.56 and <0.08, respectively.

In one study conducted in Australia, wheat treated with piperonyl butoxide at 8 mg ai/kg of grain was stored for 1, 3 or 6 months and processed to bran, pollard, germ, gluten, meal, flour and bread. Two flour extraction rates and a 1:1 blend of the two were used. The concentrations of residues increased in bran, pollard, germ and gluten, with average processing factors of 3.9 (n = 6), 2.1 (n = 3), 3.3 (n = 5) and 1.5 (n = 3), respectively. In meal, flour and bread, the concentrations decreased with average processing factors of 0.85 (n = 3), 0.31 (n = 6) and 0.30 (n = 9), respectively.

Wheat treated with two formulations at application rates of 10 and 13 mg/kg of grain and stored for up to 24 weeks was processed in three commercial mills (50 t per sample) and a pilot mill (1 t per sample). The concentrations of residues increased in bran with processing factors of 3.1–5.5 (average, 4.1; n = 10), in germ with processing factors of 2.1–4.3 (average, 3.2; n = 10) and in pollard with processing factors of 1.8–5.5 (average, 2.8; n = 6). On average, the concentration increased in whole meal, with processing factors of 0.48–2.8 (average, 1.3; n = 9), but decreased in flour, with processing factors of 0.27–0.66 (average, 0.48; n = 10).

Wheat treated with piperonyl butoxide at 10 mg/kg of grain was stored for 2 or 4 h and processed to bran, pollard, germ, meal, flour and bread. The concentration of residues increased in bran, pollard and germ, with average processing factors of 3.8, 2.4 and 2.6, respectively. The concentrations decreased in flour, meal, whole meal bread and white bread, with processing factors of 0.22, 0.78, 0.41and 0.11, respectively.

Five processing studies were conducted in Australia with wheat treated at the GAP rate or higher and stored for 7–26 weeks. The concentrations of residues increased in bran with an average processing factor of 3.8 (3.33–4.7, n = 4), in germ with an average processing factor of 2.2 (1.33–2.89, n = 4) and in gluten with a processing factor of 1.4. The concentrations decreased in flour with an average processing factor of 0.37 (0.24–0.51, n = 5), in bread (white pan, whole meal, flat Arabic and steamed) with processing factors of 0.18–0.83 (average, 0.44) and in noodles (yellow alkaline and white) with average processing factors of 0.24 and 0.28. On average, the concentrations of residues decreased in wheat whole meal, with processing factors of 0.61–1.29 (n = 4; average, 0.98).

In summary, the concentrations of piperonyl butoxide residues increased in wheat bran, with an average processing factor of 2.7 (n = 60), in germ with an average processing factor of 3.0 (n = 21), in pollard with an average processing factor of 2.15 (n = 19) and in gluten with an average

processing factor of 1.5 (n = 4). The concentrations decreased in wheat flour with an average processing factor of 0.31 (n = 58), in wheat whole meal with an average processing factor of 0.98 (n = 23), in bread with an average processing factor of 0.32 (n = 47) and in noodles, with an average processing factor of 0.26 (n = 8).

On the basis of the recommendations for cereal grains (maximum residue level of 30 mg/kg and of STMR of 11 mg/kg) and the calculated processing factors, the Meeting recommends a maximum residue level of 80 mg/kg and an STMR-P value of 29.7 mg/kg for wheat bran; a maximum residue level of 90 mg/kg and an STMR-P value of 33 mg/kg for piperonyl butoxide in wheat germ; a maximum residue level of 10 mg/kg and an STMR-P value of 3.5 mg/kg for wheat flour; a maximum residue level of 30 mg/kg and an STMR-P value of 10.8 mg/kg for wheat whole meal and a maximum residue level of 100 mg/kg and an STMR-P value of 30.8 mg/kg for piperonyl butoxide in wheat germ.

In Italy, six processing studies were conducted on maize treated with piperonyl butoxide at two rates and stored for 42 or 182 days. Degermination was conducted in the laboratory under conditions that matched the industrial procedure, by starch processing (wet conditions) and mill processing (dry conditions). The concentrations of residues in germ and oil decreased, with average processing factors of < 0.3 and < 2.7, respectively (n = 6). On the basis of the recommended MRL and the STMR value for cereal grains, the Meeting recommended a maximum residue level of 80 mg/kg and an STMR-P value of 29.7 mg/kg for maize oil, crude.

Two processing studies were conducted in France on dried and undried cargo rice treated with piperonyl butoxide at 2.5 mg/kg of grain, but only a short summary of the study was provided.

Cocoa beans and soya beans were treated with piperonyl butoxide formulations at 7.5 or 10 mg ai/kg and stored for up to 1 year. Samples were then processed and analyzed. The processing factors were 0.15–0.85 (average, 0.58; n = 10) for roasted cocoa beans and <0.1–0.53 (average, < 0.20; n = 6) for chocolate paste. The concentration of residues increased in soya oil, with processing factors of 6.18, 22 and 13 (average, 13.9), and changed little in soya cake, with processing factors of 0.86, 0.75 and 1.4 (average, 1.0). Only a summary of the studies was provided.

Residues in animal commodities

The new recommendations for pea hay and wheat bran, will be included in the dietary burden calculation of farm animal.

The Meeting estimated the dietary burden of piperonyl butoxide residues in cows and poultry on the basis of the diets listed in Appendix IX of the *FAO Manual* (FAO, 2002) and the maximum residue levels and STMR values estimated by the current and the previous Meeting.

Estimate of maximum dietary burden of farm animals

Commodity						% of diet			Residue contribution (mg/kg)		
	Group	Residues (mg/kg)	Basis	Dry matter (%)	Residues, dry weight (mg/kg)	Beef cattle	Dairy cows	Poultry	Beef cattle	Dairy cows	Poultry
Citrus, dried pulp	AB	5.7	STMR-P	91	6.2	20	10	–	1.2	0.6	–
Potato peel, wet	AB	0.15	STMR-P	20	0.27			–			–
Sorghum	GC	30	MRL	86	34.2	5		20	1.7		27.4
Wheat	GC	30	MRL	89	33.3						
Wheat bran	GC	80	MRL	89	89.9	50	40	80	44.9	36.0	71.9
Rice	GC	30	MRL	88	33.6						
Maize	GC	30	MRL	88	33.6						

Commodity	Group	Residues (mg/kg)	Basis	Dry matter (%)	Residues, dry weight (mg/kg)	% of diet			Residue contribution (mg/kg)		
						Beef cattle	Dairy cows	Poultry	Beef cattle	Dairy cows	Poultry
Pea vines	AL	400	MRL	–	400	25	50	–	100	200	–
Pea hay	AL	200	MRL	-	200						
					Total	**100**	**100**	**100**	**144.9**	**236.6**	**99.3**

Estimated STMR value for dietary burden of farm animals

Commodity	Group	Residues (mg/kg)	Basis	Dry matter (%)	Residues, dry weight (mg/kg)	% of diet			Residue contribution (mg/kg)		
						Beef cattle	Dairy cows	Poultry	Beef cattle	Dairy cows	Poultry
Citrus, dried pulp	AB	5.7	STMR-P	91	6.2	20	10	–	1.2	0.6	–
Potato peel, wet	AB	0.15	STMR-P	20	0.27			–			–
Sorghum	GC	11	STMR	86	12.5	5		20	0.6		2.5
Wheat	GC	11	STMR	89	12.2						
Wheat bran	GC	29.7	STMR	89	31.1	50	40	80	15.6	12.4	24.9
Rice	GC	11	STMR	88	12.3						
Maize	GC	11	STMR	88	12.3						
Pea vines	AL	108	STMR	–	108	25	50	–	27	54	–
Pea hay	AL	33.5	STMR	–	33.5			–			
				Total		**100**	**100**	**100**	**44.4**	**67**	**27.4**

Feeding and dermal application to animals

Cows were given diets containing piperonyl butoxide at a concentration of 100, 300, 900 or 3000 ppm (dry weight basis) once daily for 28–30 consecutive days. The average concentration of residues in milk from three cows at 100 and 300 ppm remained approximately constant throughout the dosing period within ranges of < 0.01–0.02 mg/kg and 0.03–0.07 mg/kg, respectively. The concentrations in milk reached a plateau rapidly at higher doses. The average concentration of piperonyl butoxide in milk from cows at 900 ppm was 0.41 mg/kg, and that in milk from cows at the highest dose was 5.6 mg/kg. The residues in all treated animals were concentrated in liver and fat, and none were detected in kidney or muscle at the lowest dose. In liver, the mean concentration ranged from 0.14 mg/kg at 100 ppm to 12 mg/kg at 3000 ppm. The concentrations in animals at 100 ppm and 3000 ppm were 0.21 and 146 mg/kg in fat, <0.05 and 10 mg/kg in kidney and <0.05 and 7.6 mg/kg in muscle.

In Costa Rica and the USA, piperonyl butoxide may be sprayed directly onto livestock and poultry at a rate of 0.42–8.9 g ai/animal. Three cows were treated dermally twice daily for 28 consecutive days at a maximum GAP dose of 2.28 g/day (3.78 mg/kg bw per day). The average concentration of residues in milk was 0.06 mg/kg on the first day and increased to 0.14 mg/kg on day 3, 0.12 mg/kg on day 7 and 0.16 mg/kg on day 27.

Laying hens were given diets containing 20.4, 61.2 or 199 ppm piperonyl butoxide equivalents. The concentrations of residues in eggs from hens at 61.2 ppm reached a plateau on day 7, at 0.16–0.21 mg/kg on days 7–21 and an increase on day 27. Residues were detected in liver only at the highest dietary level (at a concentration of 0.13 mg/kg). In muscle, residues were present in hens at the two higher dietary levels at mean concentrations of 0.09 and 0.74 mg/kg, respectively. The mean concentration in fat was 0.30 mg/kg at the lowest dietary level and 12 mg/kg at the highest.

Laying hens exposed dermally for 28 consecutive days to piperonyl butoxide at a GAP application rate of 37.8 g/1000 m^3 had residues in their eggs from day 3, at a concentration of

0.02 mg/kg, which increased steadily up to day 27 (0.46 mg/kg) and did not reach a plateau. The average concentrations in tissues ranged from 0.96 mg/kg in muscle to 3.0 mg/kg in fat and 5.1 mg/kg in skin.

Residues in animal products

Cattle

The maximum calculated dietary burden of piperonyl butoxide for cattle was 144.9 mg/kg feed for beef cattle and 236.6 mg/kg for dairy cows. The highest dietary burden was used to estimate the maximum residue level in milk and tissues of cattle. The mean intake calculated for dairy cattle (67 mg/kg feed) was higher than that for beef cattle (44.4 mg/kg) and was used to estimate the STMR value for milk and cattle tissues.

The highest concentrations of residues in tissues in the feeding studies and the mean value in milk after the plateau were used to estimate the maximum residue level. The values at the calculated dietary burden (236.6 mg/kg) were estimated by interpolation of values for residues found at 100 and 300 ppm in feed. The mean concentrations of residues in tissues and milk were used to estimate the STMR value. The concentration of residue at the calculated dietary burden (67 mg/kg) were estimated by interpolating the residues found at 100 ppm.

Residues in cattle milk and tissues from animals treated orally

Dose (ppm)	Piperonyl butoxide concentration (mg/kg)								
Interpolated /	Milk	Liver		Kidney		Muscle		Fat	
Actual	(mean)	Highest	Mean	Highest	Mean	Highest	Mean	Highest	Mean
MRL									
236.6 /	*0.03/*	*0.55/*		*<0.11/*		*<0.057/*		*1.3/*	
100	0.01	0.15		< 0.05		< 0.05		0.42	
300	0.04	0.73		0.14		0.06		1.7	
STMR									
67 /	*0.007/*		*0.094/*		*<0.034/*		*<0.034/*		*0.14/*
100	0.01		0.14		<0.05		<0.05		0.21

The mean concentration of residue in milk after dermal treatment was used to estimate the maximum residue level and the typical value for cattle milk. The highest and median concentrations in tissues were used to estimate the maximum residue level and the typical value, respectively (FAO Manual, 2002, pg. 81).

Residues in cattle milk and tissues from animals treated dermally

Piperonyl butoxide concentration (mg/kg)								
Milk	Liver		Kidney		Muscle		Fat	
(mean)	Highest	Median	Highest	Median	Highest	Median	Highest	Median
0.14	*0.14*	*0.03*	*0.21*	*0.21*	*0.21*	*0.16*	*2.7*	*2.6*

The concentrations of residues in milk, kidney, muscle and fat from cows treated dermally are higher than those from cows fed piperonyl butoxide and will be used in the estimations for cattle. The Meeting estimated a maximum residue level for piperonyl butoxide of 0.2 mg/kg in cattle milk, 0.3 mg/kg in cattle kidney and 5 mg/kg in cattle meat (fat).

The Meeting estimated values for typical piperonyl butoxide median residues after direct use of 0.14 mg/kg in cattle milk, 0.21 mg/kg in cattle kidney, 0.16 mg/kg in cattle muscle and 2.6 mg/kg in cattle meat (fat). These values can be used in the same way as STMR values for long-term intake estimations on residue concentrations in tissues and milk (FAO Manual, 2002, pg. 81).

The concentration of residues in liver from cows fed piperonyl butoxide is higher than from cows treated dermally and will be used for the estimations. The Meeting recommends maximum residue level of 1 mg/kg, and a STMR of 0.094 mg/kg for piperonyl butoxide in liver of cattle, goats, pigs ans sheep.

The Meeting also estimates a maximum residue level of 0.05 mg/kg and a STMR of 0.007 mg/kg for milk of mammals, except cattle; a maximum residue 0.2 mg/kg and a STMR of 0.034 mg/kg for kidney of goats, pigs and sheep and a maximum residue level of 2 mg/kg and a STMR of 0.14 mg/kg for meat (fat) (from mammals other than marine mammals, except cattle). The Meeting also estimates a STMR of 0.034 mg/kg of muscle (from mammals other than marine mammals, except cattle).

Poultry

The calculated maximum and mean intakes of piperonyl butoxide for poultry, 99.3 and 27.4 mg/kg feed respectively, were used in the estimations for tissues and egg. For the estimation of the maximum residue level in tissues, the values at the calculated dietary burden (99.3 mg/kg feed) were estimated by interpolation from the highest residue values at 61.2 and 199 ppm in feed. For the STMR estimation, the values at the 27.4 mg/kg feed dietary burden were estimated by interpolation of the mean residue data at 20.4 and 61.2 ppm. For eggs, the highest and the mean values after residues plateau (7 days) were used for the estimations of maximum residue level and STMR.

Residues in poultry products from poultry treated orally

Dose (ppm)	Piperonyl butoxide (mg/kg)							
Interpolated /	Eggs		Liver		Muscle		Fat	
Actual	Highest	Mean	Highest	Mean	Highest	Mean	Highest	Mean
MRL								
99.3/	0.88/		<0.08/		0.38/		5.6/	
61.2	0.35		< 0.05		0.12		1.7	
199	1.9		0.15		0.88		13	
STMR								
27.4 /		0.056/		<0.01/		<0.058/		0.52/
20.4		0.03		–		< 0.05		0.30
61.2		0.18		< 0.05		0.09		1.3

For poultry dermally treated, the highest and median concentrations of residues in tissues and eggs (at day 27, no plateau reached) were used for the estimations.

Residues in poultry products from poultry treated dermally.

Piperonyl butoxide (mg/kg)									
Eggs		Liver		Skin		Muscle		Fat	
Highest	Median	Highest	Median	Highest	Median	Highest	Median	Highest	Median
0.79	*0.36*	*0.44*	*0.26*	*8.3*	*3.8*	*1.2*	*1.0*	*5.0*	*2.0*

The residues in poultry products in higher in the dermal study and will be used in the estimations. The Meeting recommends a maximum residue level of 1 mg/kg for eggs, a maximum residue level of 10 mg/kg in poultry edible offal (based on liver and skin), and a maximum residue level of 7 mg/kg for poultry meat (fat). The medium residue levels will be used to estimate a typical medium residue level of piperonyl butoxide in eggs of 0.36 mg/kg, of 2.0 mg/kg in poultry edible offal (mean of 0.26 and 3.8 mg/kg), of 2 mg/kg in poultry meat (fat) and of 1.0 mg/kg in poultry muscle. These values can be used in the same way as STMR values for estimating long-term dietary intake.

RECOMMENDATIONS

On the basis of the results of the supervised trials, the Meeting concluded that the concentrations of residue shown below are suitable for establishing MRLs and for assessing dietary intake.

Definition of the residue (for compliance with MRLs and for estimating dietary intake from plant and animal commodities): piperonyl butoxide.

The residue is fat-soluble.

CCN	Commodity	MRL (mg/kg)		STMR or STMR-P (mg/kg)
		New	Previous	
MO 1280	Cattle kidney	0.3 [1]		0.21(fat) [1,2]
MM 0812	Cattle meat	5 (fat) [1]		2.6 [1,2]
ML 0812	Cattle milk	0.2 F [1]		0.14 [1,2]
	Cattle muscle			0.16 [1,2]
GC 0080	Cereal grains	30 Po		11 Po
FC 0001	Citrus fruits	5		1.0
AB 0001	Citrus pulp, dry			5.7
JF 0001	Citrus juice	0.05		0.01
DM 0001	Citrus molasses			0.53
DF 0167	Dried fruits	0.2 Po		0.05 Po
PE 0112	Eggs	1 [1]		0.36 [1,2]
VC 0045	Fruiting vegetables, curcubits	1		0.26
MO 098	Kidney of goats, pigs and sheep	0.2		0.034
VL 0483	Lettuce, Leaf	50		38
MO 099	Liver of cattle, goats, pigs and sheep	1		0.094
OC 0645	Maize oil, crude	80 PoP		29.7
MM 0095	Meat (from mammals others than marine mammals), except cattle	2 (fat)		0.14 (fat)
	Muscle (from mammals others than marine mammals), except cattle			0.034
ML 0106	Milks, except cattle milk	0.05 F		0.007
VL 0485	Mustard greens	50		38
AL 0072	Pea hay or pea fodder	200 dry wt		33.5 dry wt
AL 0528	Pea vine (green)	400 dry wt		108 dry wt
SO 0703	Peanut, whole	1 Po		0.1 Po
VO 0051	Peppers	2		0.675
	Potato peel, wet			0.15
PO 0111	Poultry Edible offal of	10 [1]		2.0 [1,2]
PM 0110	Poultry meat	7 (fat) [1]		2.0 (fat) [1,2]

CCN	Commodity	MRL (mg/kg)		STMR or STMR-P (mg/kg)
		New	Previous	
	Poultry muscle			1.0 [1,2]
VD 0070	Pulses	0.2 Po		0.05 Po
VL 0494	Radish leaves	50		38
VR 0075	Root and tuber vegetables, except carrots	0.5		0.10
VL 0502	Spinach	50		38
VO 0448	Tomato	2		0.675
JF 0448	Tomato juice	0.3		0.10
	Tomato purée			0.22
GC 0654	Wheat	30 Po	10 Po	11
CM 0654	Wheat bran, unprocessed	80 PoP		29.7 PoP
CF 1211	Wheat flour	10 PoP		3.5 PoP
CF 1210	Wheat germ	90 PoP		33 PoP
CF 1212	Wheat wholemeal	30 PoP		10.8 PoP

[1] The MRL accommodates external animal treatment
[2] Not STMR value but median residue concentrations in animals in a treated group

DIETARY RISK ASSESSMENT

Long-term intake

Currently, the ADI for piperonyl butoxide is 0.2 mg/kg bw. IEDIs were calculated for commodities for human consumption for which STMR values had been estimated by the present Meeting. The results are shown in Annex 3.

The IEDIs for the five GEMS/Food regional diets, on the basis of the estimated STMRs, ranged from 20 to 40% of the ADI. The Meeting concluded that the intake of residues of piperonyl butoxide resulting from its uses that have been considered by the JMPR is unlikely to present a public heath concern.

Short-term intake

The 2001 JMPR concluded that an acute RfD for piperonyl butoxide was unnecessary. The Meeting therefore concluded that short-term dietary intake of piperonyl butoxide residues is unlikely to present a risk to consumers.