

# End mission report Kassala cold room project

## **Initial assessments**

The mission in object foresaw the feasibility study and subsequent analysis of the creation of a cold room for the storage of perishable foodstuffs. Specifically, fruit and vegetables grown in the area around Kassala. In particular fruit such as mangoes, bananas, oranges, grapefruits. While for the vegetable the request was for potatoes, onions and tomatoes. At the beginning of the assignment I held some meetings in Italy with companies in the sector to gather as much information as possible. So as to have more information possible to be used in the study and evaluation of the project. In particular, the temperatures of the products to be stored have been evaluated, with some critical issues emerging as a function of the products. Below is a table that takes into consideration all the products that can be treated inside a cold store (only fruit and vegetables in our case). The maintenance temperature and humidity of the various products, the average storage time are highlighted. Other values such as production and sensitivity to ethylene are also indicated, important data to understand if a controlled environment cell is worth. In addition, the breathing rate is also highlighted, another important value necessary for the design of the cold room. The products that will be stored are highlighted in yellow in the following tables. The tables are provided by Emerson Inc. To be considered as guidelines. If you want to deepen further you can visit the link: <http://postharvest.ucdavis.edu>. It immediately becomes evident that the storage temperature values between fruit and vegetables are different. In some cases there are about 13 ° C. While humidity, production and sensitivity to ethanol can be considered negligible from the point of view of conservation. As the mango is the fruit that can be considered more profitable economically, we tried to evaluate all the aspects necessary for an effective maintenance in the longest possible period. Research has been made out and some studies carried out for this purpose have been taken into consideration. In particular, a study performed by the University of Los Banos (Philippines). The study focuses on the possibility of storing the product for a longer period at a lower temperature. So as to have more time for distribution on the market, to the advantage of economic gains. Moreover, a lower mass reduction, which translates into greater gain, if the sale is made by weight not by unit. It should also be noted that this conditioning can be taken into consideration if the product wants to be exported, exploiting a more complex cold chain. Which foresees, as well as cold rooms, also refrigerated trucks for transport on wheels and possible export by ships also used to transport refrigerated containers. (The complete report is inserted as an attachment)

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**Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (Continued)**

| Common Name<br>(Other Common Name) | Scientific<br>Name                                | Storage<br>Temp.,<br>°C | Relative<br>Humid-<br>ity, % | Highest<br>Freezing<br>Temp.,<br>°C | Ethylene<br>Production<br>Rate <sup>a</sup> | Ethylene<br>Sensitivity <sup>b</sup> | Respi-<br>ration<br>Rate <sup>c</sup> | Approximate<br>Postharvest<br>Life | Observations<br>and Beneficial<br>CA <sup>d</sup> Conditions |
|------------------------------------|---|-------------------------|------------------------------|-------------------------------------|---|--------------------------------------|---------------------------------------|------------------------------------|--|
| Blueberry                          | <i>Vaccinium corymbosum</i>                       | -0.5 to 0               | 90 to 95                     | -1.3                                | Low   | Low                                  | Low                                   | 10 to 18 days                      | 2 to 5% O <sub>2</sub><br>12 to 20% CO <sub>2</sub>          |
| Cranberry                          | <i>Vaccinium macrocarpon</i>                      | 2 to 5                  | 90 to 95                     | -0.9                                | Low   | Low                                  | Low                                   | 8 to 16 weeks                      | 1 to 2% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>            |
| Dewberry                           | <i>Rubus</i> spp.                                 | -0.5 to 0               | 90 to 95                     | -1.3                                | Low   | Low                                  |                                       | 2 to 3 days                        |  |
| Elderberry                         | <i>Rubus</i> spp.                                 | -0.5 to 0               | 90 to 95                     | -0.9                                | Low   | Low                                  |                                       | 5 to 14 days                       |  |
| Loganberry                         | <i>Rubus</i> spp.                                 | -0.5 to 0               | 90 to 95                     | -1.3                                | Low   | Low                                  |                                       | 2 to 3 days                        |  |
| Raspberry                          | <i>Rubus idaeus</i>                               | -0.5 to 0               | 90 to 95                     | -0.9                                | Low   | Low                                  | Moderate                              | 3 to 6 days                        | 5 to 10% O <sub>2</sub><br>15 to 20% CO <sub>2</sub>         |
| Strawberry                         | <i>Fragaria</i> spp.                              | 0                       | 90 to 95                     | -0.8                                | Low   | Low                                  | Low                                   | 7 to 10 days                       | 5 to 10% O <sub>2</sub><br>15 to 20% CO <sub>2</sub>         |
| Bittermelon (bitter melon)         | <i>Momordica</i>                                  | 10 to 12                | 85 to 90                     |                                     | Low   | Moderate                             | Moderate                              | 2 to 3 weeks                       | 2 to 3% O <sub>2</sub><br>5% CO <sub>2</sub>                 |
| Black salsify (scorzonera)         | <i>Scorzonera hispanica</i>                       | 0 to 1                  | 95 to 98                     |                                     | Very low                                    | Low                                  |                                       | 6 months                           |  |
| Bok choy                           | <i>Brassica chinensis</i>                         | 0                       | 95 to 100                    |                                     | Very low                                    | High                                 |                                       | 3 weeks                            |  |
| Breadfruit                         | <i>Artocarpus altilis</i>                         | 13 to 15                | 85 to 90                     |                                     |   |                                      |                                       | 2 to 4 weeks                       |  |
| Broccoli                           | <i>Brassica oleracea</i> var. <i>Italica</i>      | 0                       | 95 to 100                    | -0.6                                | Very low                                    | High                                 | Moderate                              | 10 to 14 days                      | 1 to 2% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>           |
| Brussels sprouts                   | <i>Brassica oleracea</i> var. <i>Gemmifera</i>    | 0                       | 95 to 100                    | -0.8                                | Very low                                    | High                                 | Moderate                              | 3 to 5 weeks                       | 1 to 2% O <sub>2</sub><br>5 to 7% CO <sub>2</sub>            |
| Cabbage                            |   |                         |                              |                                     |   |                                      |                                       |                                    |  |
| Chinese (Napa)                     | <i>Brassica campestris</i> var. <i>Pekinensis</i> | 0                       | 95 to 100                    | -0.9                                | Very low                                    | High                                 | Low                                   | 2 to 3 months                      | 1 to 2% O <sub>2</sub><br>0 to 6% CO <sub>2</sub>            |
| Common, early crop                 | <i>Brassica oleracea</i> var. <i>Capitata</i>     | 0                       | 98 to 100                    | -0.9                                | Very low                                    | High                                 | Low                                   | 3 to 6 weeks                       |  |
| Common, late crop                  | <i>Brassica oleracea</i> var. <i>Capitata</i>     | 0                       | 95 to 100                    | -0.9                                | Very low                                    | High                                 | Low                                   | 5 to 6 months                      | 3 to 5% O <sub>2</sub><br>3 to 7% CO <sub>2</sub>            |
| Cactus leaves (nopalitos)          | <i>Opuntia</i> spp.                               | 5 to 10                 | 90 to 95                     |                                     | Very low                                    | Moderate                             |                                       | 2 to 3 weeks                       |  |
| Cactus fruit (prickly pear fruit)  | <i>Opuntia</i> spp.                               | 5                       | 85 to 90                     | -1.8                                | Very low                                    | Moderate                             |                                       | 2 to 6 weeks                       |  |
| Caimito                            | see Sapotes                                       |                         |                              |                                     |   |                                      |                                       |                                    |  |
| Calamondin                         | see Citrus  |                         |                              |                                     |   |                                      |                                       |                                    |  |
| Canistel                           | see Sapotes                                       |                         |                              |                                     |   |                                      |                                       |                                    |  |
| Carambola (starfruit)              | <i>Averrhoa carambola</i>                         | 9 to 10                 | 85 to 90                     | -1.2                                |   |                                      | Low                                   | 3 to 4 weeks                       |  |
| Carrot                             |   |                         |                              |                                     |   |                                      |                                       |                                    |  |
| Topped                             | <i>Daucus carota</i>                              | 0                       | 98 to 100                    | -1.4                                | Very low                                    | High                                 | Low                                   | 3 to 6 months                      | No CA benefit  |
| Bunched, immature                  | <i>Daucus carota</i>                              | 0                       | 98 to 100                    | -1.4                                | Very low                                    | High                                 | Moderate                              | 10 to 14 days                      | Ethylene causes bitterness                                   |
| Cashew, apple                      | <i>Anacardium occidentale</i>                     | 0 to 2                  | 85 to 90                     |                                     |   |                                      |                                       | 5 weeks                            |  |
| Cassava (yucca, manioc)            | <i>Manihot esculenta</i>                          | 0 to 5                  | 85 to 90                     |                                     | Very low                                    | Low                                  | Low                                   | 1 to 2 months                      | No CA benefit  |
| Cauliflower                        | <i>Brassica oleracea</i> var. <i>Botrytis</i>     | 0                       | 95 to 98                     | -0.8                                | Very low                                    | High                                 | Moderate                              | 3 to 4 weeks                       | 2 to 5% O <sub>2</sub><br>2 to 5% CO <sub>2</sub>            |
| Celeriac                           | <i>Apium graveolens</i> var. <i>Rapaceum</i>      | 0                       | 98 to 100                    | -0.9                                | Very low                                    | Low                                  | Low                                   | 6 to 8 months                      | 2 to 4% O <sub>2</sub><br>2 to 3% CO <sub>2</sub>            |
| Celery                             | <i>Apium graveolens</i> var. <i>Dulce</i>         | 0                       | 98 to 100                    | -0.5                                | Very low                                    | Moderate                             | Low                                   | 1 to 2 months                      | 1 to 4% O <sub>2</sub><br>3 to 5% CO <sub>2</sub>            |
| Chard                              | <i>Beta vulgaris</i> var. <i>Cida</i>             | 0                       | 95 to 100                    |                                     | Very low                                    | High                                 |                                       | 10 to 14 days                      |  |
| Chayote                            | <i>Sechium edule</i>                              | 7                       | 85 to 90                     |                                     |   |                                      | Low                                   | 4 to 6 weeks                       |  |
| Cherimoya (custard apple)          | <i>Annona cherimola</i>                           | 13                      | 90 to 95                     | -2.2                                | High  | High                                 | Very high                             | 2 to 4 weeks                       | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>           |
| Cherries                           |   |                         |                              |                                     |   |                                      |                                       |                                    |  |
| Sour                               | <i>Prunus cerasus</i>                             | 0                       | 90 to 95                     | -1.7                                |   |                                      | Low                                   | 3 to 7 days                        | 3 to 10% O <sub>2</sub><br>10 to 12% CO <sub>2</sub>         |
| Sweet                              | <i>Prunus avium</i>                               | -1 to 0                 | 90 to 95                     | -2.1                                |   |                                      | Low                                   | 2 to 3 weeks                       | 10 to 20% O <sub>2</sub><br>20 to 25% CO <sub>2</sub>        |
| Chicory                            | see Endive  |                         |                              |                                     |   |                                      |                                       |                                    |  |

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**Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons**

| Common Name<br>(Other Common Name) | Scientific Name  | Storage Temp., °C | Relative Humidity, % | Highest Freezing Temp., °C | Ethylene Production Rate <sup>a</sup> | Ethylene Sensitivity <sup>b</sup> | Respiration Rate <sup>c</sup> | Approximate Postharvest Life | Observations and Beneficial CA <sup>d</sup> Conditions |
|------------------------------------|--|-------------------|----------------------|----------------------------|---------------------------------------|-----------------------------------|-------------------------------|------------------------------|--|
| Acerola (Barbados cherry)          | <i>Malpighia glabra</i>  | 0                 | 85 to 90             | -1.4                       |                                       |                                   |                               | 6 to 8 weeks                 |  |
| African horned melon (kiwano)      | <i>Cucumis africanus</i>                                       | 13 to 15          | 90                   |                            | Low                                   | Moderate                          |                               | 3 to 6 months                |  |
| Amaranth (pigweed)                 | <i>Amaranthus</i> spp.   | 0 to 2            | 95 to 100            |                            | Very low                              | Moderate                          |                               | 10 to 14 days                |  |
| Anise (fennel)                     | <i>Foeniculum vulgare</i>                                      | 0 to 2            | 90 to 95             | -1.1                       |                                       |                                   |                               | 2 to 3 weeks                 |  |
| Apple                              |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Not chilling sensitive             | <i>Malus pumila</i>  | -1                | 90 to 95             | -1.5                       | Very high                             | High                              | Low                           | 3 to 6 months                | 2 to 3% O <sub>2</sub><br>1 to 2% CO <sub>2</sub>      |
| Chilling sensitive                 | <i>Malus pumila</i> cv. Yellow Newton, Grimes golden, McIntosh | 4                 | 90 to 95             | -1.5                       | Very high                             | High                              | Low                           | 1 to 2 months                | 2 to 3% O <sub>2</sub><br>1 to 2% CO <sub>2</sub>      |
| Apricot                            | <i>Prunus armeniaca</i>  | -0.5 to 0         | 90 to 95             | -1.1                       | Moderate                              | Moderate                          | Low                           | 1 to 3 weeks                 | 2 to 3% O <sub>2</sub><br>2 to 3% CO <sub>2</sub>      |
| Artichokes                         |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Chinese                            | <i>Stachys affinia</i>   | 0                 | 90 to 95             |                            | Very low                              | Very Low                          |                               | 1 to 2 weeks                 |  |
| Globe                              | <i>Cynara scolymus</i>   | 0                 | 95 to 100            | -1.2                       | Very low                              | Low                               | High                          | 2 to 3 weeks                 | 2 to 3% O <sub>2</sub><br>3 to 5% CO <sub>2</sub>      |
| Jerusalem                          | <i>Helianthus tuberosus</i>                                    | -0.5 to 0         | 90 to 95             | -2.5                       | Very low                              | Low                               | Low                           | 4 months                     |  |
| Arugula                            | <i>Eruca vesicaria</i> var. <i>sativa</i>                      | 0                 | 95 to 100            |                            | Very low                              | High                              | Moderate                      | 7 to 10 days                 |  |
| Asian pear (nashi)                 | <i>Pyrus serotina</i> <i>P. pyrifolia</i>                      | 1                 | 90 to 95             | -1.6                       | High                                  | High                              | Low                           | 4 to 6 months                |  |
| Asparagus, green or white          | <i>Asparagus officinalis</i>                                   | 2.5               | 95 to 100            | -0.6                       | Very low                              | Moderate                          | Very high                     | 2 to 3 weeks                 | 5 to 12% CO <sub>2</sub>                               |
| Atemoya                            | <i>Annona squamosa</i> x <i>A. cherimola</i>                   | 13                | 85 to 90             |                            | High                                  | High                              |                               | 2 to 4 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>     |
| Avocado                            |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Fuchs, Pollock                     | <i>Persea americana</i> cv. Fuchs, Pollock                     | 13                | 85 to 90             | -0.9                       | High                                  | High                              | Moderate                      | 2 weeks                      |  |
| Fuerte, Hass                       | <i>Persea americana</i> cv. Fuerte, Hass                       | 3 to 7            | 85 to 90             | -1.6                       | High                                  | High                              | Moderate                      | 2 to 4 weeks                 | 2 to 5% O <sub>2</sub><br>3 to 10% CO <sub>2</sub>     |
| Lula, Booth                        | <i>Persea americana</i> cv. Lula, Booth                        | 4                 | 90 to 95             | -0.9                       | High                                  | High                              | Moderate                      | 4 to 8 weeks                 |  |
| Babaco (mountain papaya)           | <i>Carica candamarcensis</i>                                   | 7                 | 85 to 90             |                            |                                       |                                   |                               | 1 to 3 weeks                 |  |
| Banana                             | <i>Musa paradisiaca</i> var. <i>sapientum</i>                  | 13 to 15          | 90 to 95             | -0.8                       | Moderate                              | High                              | Low                           | 1 to 4 weeks                 | 2 to 5% O <sub>2</sub><br>2 to 5% CO <sub>2</sub>      |
| Barbados cherry                    | see Acerola  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Beans                              |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Fava (broad)                       | <i>Vicia faba</i>  | 0                 | 90 to 95             |                            |                                       |                                   |                               | 1 to 2 weeks                 |  |
| Lima                               | <i>Phaseolus lunatus</i>                                       | 5 to 6            | 95                   | -0.6                       | Low                                   | Moderate                          | Moderate                      | 5 to 7 days                  |  |
| Long (yard-long)                   | <i>Vigna sesquipedalis</i>                                     | 4 to 7            | 90 to 95             |                            | Low                                   | Moderate                          |                               | 7 to 10 days                 |  |
| Snap (wax, green)                  | <i>Phaseolus vulgaris</i>                                      | 4 to 7            | 95                   | -0.7                       | Low                                   | Moderate                          | Moderate                      | 7 to 10 days                 | 2 to 3% O <sub>2</sub><br>4 to 7% CO <sub>2</sub>      |
| Winged                             | <i>Psophocarpus tetragonolobus</i>                             | 10                | 90                   |                            |                                       |                                   |                               | 4 weeks                      |  |
| Beet                               |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Bunched                            | <i>Beta vulgaris</i>   | 0                 | 98 to 100            | -0.4                       | Very low                              | Low                               | Low                           | 10 to 14 days                |  |
| Topped                             | <i>Beta vulgaris</i>   | 0                 | 98 to 100            | -0.9                       | Very low                              | Low                               | Low                           | 4 months                     |  |
| Berries                            |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Blackberry                         | <i>Rubus</i> spp.  | -0.5 to 0         | 90 to 95             | -0.8                       | Low                                   | Low                               | Moderate                      | 3 to 6 days                  | 5 to 10% O <sub>2</sub><br>15 to 20% CO <sub>2</sub>   |

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**Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (Continued)**

| Common Name<br>(Other Common Name)  | Scientific Name  | Storage Temp., °C | Relative Humidity, % | Highest Freezing Temp., °C | Ethylene Production Rate <sup>a</sup> | Ethylene Sensitivity <sup>b</sup> | Respiration Rate <sup>c</sup> | Approximate Postharvest Life | Observations and Beneficial CA <sup>d</sup> Conditions                              |
|-------------------------------------|--|-------------------|----------------------|----------------------------|---------------------------------------|-----------------------------------|-------------------------------|------------------------------|---|
| Chiles                              | see Peppers  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Chinese broccoli (gailan)           | <i>Brassica alboglabra</i>                                 | 0                 | 95 to 100            |                            | Very low                              | High                              |                               | 10 to 14 days                |   |
| Chives                              | <i>Allium schoenoprasum</i>                                | 0                 | 95 to 100            |                            | Very low                              | High                              |                               | 2 to 3 weeks                 |   |
| Cilantro (Chinese parsley)          | <i>Coriandrum sativum</i>                                  | 0 to 2            | 95 to 100            |                            | Very low                              | High                              | High                          | 2 weeks                      |   |
| Citrus                              |  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Calamondin orange                   | <i>Citrus reticulata</i> x. <i>Fortunella</i> spp.         | 9 to 10           | 90                   | -2.0                       |                                       |                                   | Low                           | 2 weeks                      |   |
| <b>Grapefruit</b>                   |  |                   |                      |                            |                                       |                                   |                               |                              |   |
| CA, AZ, dry areas                   | <i>Citrus paradisi</i>                                     | 14 to 15          | 85 to 90             | -1.1                       | Very low                              | Moderate                          | Low                           | 6 to 8 weeks                 | 3 to 10% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                 |
| FL, humid areas                     | <i>Citrus paradisi</i>                                     | 10 to 15          | 85 to 90             | -1.1                       | Very low                              | Moderate                          | Low                           | 6 to 8 weeks                 | 3 to 10% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                 |
| Kumquat                             | <i>Fortunella japonica</i>                                 | 4                 | 90 to 95             |                            |                                       |                                   | Low                           | 2 to 4 weeks                 |   |
| Lemon                               | <i>Citrus limon</i>  | 10 to 13          | 85 to 90             | -1.4                       |                                       |                                   | Low                           | 1 to 6 months                | 5 to 10% O <sub>2</sub><br>0 to 10% CO <sub>2</sub><br>Store at 0 to 4°C for <1 mo. |
| Lime (Mexican, Tahitian or Persian) | <i>Citrus aurantifolia</i> ; <i>C. latifolia</i>           | 9 to 10           | 85 to 90             | -1.6                       |                                       |                                   | Low                           | 6 to 8 weeks                 | 5 to 10% O <sub>2</sub><br>0 to 10% CO <sub>2</sub>                                 |
| <b>Orange</b>                       |  |                   |                      |                            |                                       |                                   |                               |                              |   |
| CA, AZ, dry areas                   | <i>Citrus sinensis</i>                                     | 3 to 9            | 85 to 90             | -0.8                       | Very low                              | Moderate                          | Low                           | 3 to 8 weeks                 | 5 to 10% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>                                  |
| FL, humid areas                     | <i>Citrus sinensis</i>                                     | 0 to 2            | 85 to 90             | -0.8                       | Very low                              | Moderate                          | Low                           | 8 to 12 weeks                | 5 to 10% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>                                  |
| Blood orange                        | <i>Citrus sinensis</i>                                     | 4 to 7            | 90 to 95             | -0.8                       |                                       |                                   | Low                           | 3 to 8 weeks                 | 5 to 10% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>                                  |
| Seville (sour)                      | <i>Citrus aurantium</i>                                    | 10                | 85 to 90             | -0.8                       | Low                                   |                                   | Low                           | 12 weeks                     |   |
| Pomelo                              | <i>Citrus grandis</i>                                      | 7 to 9            | 85 to 90             | -1.6                       |                                       |                                   | Low                           | 12 weeks                     |   |
| Tangelo (minneola)                  | <i>Citrus reticulata</i> x <i>paradisi</i>                 | 7 to 10           | 85 to 95             | -0.9                       |                                       |                                   | Low                           |                              |   |
| Tangerine (mandarin)                | <i>Citrus reticulata</i>                                   | 4 to 7            | 90 to 95             | -1.1                       | Very low                              | Moderate                          | Low                           | 2 to 4 weeks                 |   |
| Coconut                             | <i>Cocos nucifera</i>                                      | 0 to 2            | 89 to 85             | -0.9                       |                                       |                                   |                               | 1 to 2 months                |   |
| Collards and kale                   | <i>Brassica oleracea</i> var. <i>Acephala</i>              | 0                 | 95 to 100            | -0.5                       | Very low                              | High                              | High                          | 10 to 14 days                |   |
| Corn, sweet and baby                | <i>Zea mays</i>  | 0                 | 95 to 98             | -0.6                       | Very low                              | Low                               | High                          | 5 to 8 days                  | 2 to 4% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                  |
| Cucumber                            | <i>Cucumis sativus</i>                                     | 10 to 12          | 85 to 90             | -0.5                       | Low                                   | High                              | Low                           | 10 to 14 days                | 3 to 5% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>                                   |
| Cucumber, pickling                  | <i>Cucumis sativus</i>                                     | 4                 | 95 to 100            |                            | Low                                   | High                              |                               | 7 days                       | 3 to 5% O <sub>2</sub><br>3 to 5% CO <sub>2</sub>                                   |
| Currants                            | <i>Ribes sativum</i> ; <i>R. nigrum</i> ; <i>R. rubrum</i> | -0.5 to 0         | 90 to 95             | -1.0                       | Low                                   | Low                               |                               | 1 to 4 weeks                 |   |
| Custard apple                       | see Cherimoya  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Daikon (Oriental radish)            | <i>Raphanus sativus</i>                                    | 0 to 1            | 95 to 100            |                            | Very low                              | Low                               |                               | 4 months                     |   |
| Dasheen                             | see Taro   |                   |                      |                            |                                       |                                   |                               |                              |   |
| Date                                | <i>Phoenix dactylifera</i>                                 | -18 to 0          | 75                   | -15.7                      | Very low                              | Low                               | Low                           | 6 to 12 months               |   |
| Dill                                | see Herbs  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Durian                              | <i>Durio zibethinus</i>                                    | 4 to 6            | 85 to 90             |                            |                                       |                                   |                               | 6 to 8 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 15% CO <sub>2</sub>                                  |
| Eggplant                            | <i>Solanum melongena</i>                                   | 10 to 12          | 90 to 95             | -0.8                       | Low                                   | Moderate                          | Low                           | 1 to 2 weeks                 | 3 to 5% O <sub>2</sub><br>0% CO <sub>2</sub>  |
| Endive (escarole)                   | <i>Cichorium endivia</i>                                   | 0                 | 95 to 100            | -0.1                       | Very low                              | Moderate                          | High                          | 2 to 4 weeks                 |   |

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| Common Name<br>(Other Common Name)  | Scientific Name  | Storage Temp., °C | Relative Humidity, % | Highest Freezing Temp., °C | Ethylene Production Rate <sup>a</sup> | Ethylene Sensitivity <sup>b</sup> | Respiration Rate <sup>c</sup> | Approximate Postharvest Life | Observations and Beneficial CA <sup>d</sup> Conditions  |
|-------------------------------------|--|-------------------|----------------------|----------------------------|---------------------------------------|-----------------------------------|-------------------------------|------------------------------|---|
| Belgian endive<br>(Witloof chicory) | <i>Cichorium intybus</i>                                   | 2 to 3            | 95 to 98             |                            | Very low                              | Moderate                          |                               | 2 to 4 weeks                 | Light causes greening<br>3 to 4% O <sub>2</sub><br>4 to 5% C <sub>2</sub>   |
| Feijoa (pineapple guava)            | <i>Feijoa selloiana</i>                                    | 5 to 10           | 90                   |                            | Moderate                              | Low                               |                               | 2 to 3 weeks                 |   |
| Fennel                              | see Anise  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Fig, fresh                          | <i>Ficus carica</i>  | -0.5 to 0         | 85 to 90             | -2.4                       | Moderate                              | Low                               | Low                           | 7 to 10 days                 | 5 to 10% O <sub>2</sub><br>15 to 20% CO <sub>2</sub>  |
| Garlic                              | <i>Allium sativum</i>                                      | 0                 | 65 to 70             | -0.8                       | Very low                              | Low                               | Low                           | 6 to 7 months                | 0.5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>   |
| Ginger                              | <i>Zingiber officinale</i>                                 | 13                | 65                   |                            | Very low                              | Low                               |                               | 6 months                     | No CA benefit   |
| Gooseberry                          | <i>Ribes grossularia</i>                                   | -0.5 to 0         | 90 to 95             | -1.1                       | Low                                   | Low                               | Low                           | 3 to 4 weeks                 |   |
| Granadilla                          | see Passionfruit   |                   |                      |                            |                                       |                                   |                               |                              |   |
| Grape <sup>e</sup>                  |  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Table grape                         | <i>Vitis vinifera</i>                                      | -0.5 to 0         | 90 to 95             | -2.7                       | Very low                              | Low                               | Low                           | 1 to 6 months                | 2 to 5% O <sub>2</sub><br>1 to 3% CO <sub>2</sub><br>to 4 weeks: 5 to 10% O <sub>2</sub><br>10 to 15% CO <sub>2</sub> |
| American grape                      | <i>Vitis labrusca</i>                                      | -1 to -0.5        | 90 to 95             | -1.4                       | Very low                              | Low                               | Low                           | 2 to 8 weeks                 |   |
| Grapefruit                          | see Citrus   |                   |                      |                            |                                       |                                   | Low                           |                              |   |
| Guava                               | <i>Psidium guajava</i>                                     | 5 to 10           | 90                   |                            | Low                                   | Moderate                          | Moderate                      | 2 to 3 weeks                 |   |
| Herbs, fresh culinary               |  |                   |                      |                            |                                       |                                   |                               |                              | 5 to 10% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>   |
| Basil                               | <i>Ocimum basilicum</i>                                    | 10                | 90                   |                            | Very low                              | High                              |                               | 7 days                       |   |
| Chives                              | <i>Allium schoenorassum</i>                                | 0                 | 95 to 100            | -0.9                       | Low                                   | Moderate                          |                               |                              |   |
| Dill                                | <i>Anethum graveolens</i>                                  | 0                 | 95 to 100            | -0.7                       | Very low                              | High                              |                               | 1 to 2 weeks                 |   |
| Epazote                             | <i>Chenopodium ambrosioides</i>                            | 0 to 5            | 90 to 95             |                            | Very low                              | Moderate                          |                               | 1 to 2 weeks                 |   |
| Mint                                | <i>Mentha</i> spp.   | 0                 | 95 to 100            |                            | Very low                              | High                              |                               | 2 to 3 weeks                 |   |
| Oregano                             | <i>Origanum vulgare</i>                                    | 0 to 5            | 90 to 95             |                            | Very low                              | Moderate                          |                               | 1 to 2 weeks                 |   |
| Parsley                             | <i>Petroselinum crispum</i>                                | 0                 | 95 to 100            | -1.1                       | Very low                              | High                              | Very high                     | 1 to 2 months                |   |
| Perilla (shiso)                     | <i>Perilla frutescens</i>                                  | 10                | 95                   |                            | Very low                              | Moderate                          |                               | 7 days                       |   |
| Sage                                | <i>Salvia officinalis</i>                                  | 0                 | 90 to 95             |                            |                                       |                                   |                               | 2 to 3 weeks                 |   |
| Thyme                               | <i>Thymus vulgaris</i>                                     | 0                 | 90 to 95             |                            |                                       |                                   |                               | 2 to 3 weeks                 |   |
| Horseradish                         | <i>Amoracia rusticana</i>                                  | -1 to 0           | 98 to 100            | -1.8                       | Very low                              | Low                               |                               | 10 to 12 months              |   |
| Husk tomato                         | see Tomatillo  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Jaboticaba                          | <i>Myrciaria cauliflora</i> =<br><i>Eugenia cauliflora</i> | 13 to 15          | 90 to 95             |                            |                                       |                                   |                               | 2 to 3 days                  |   |
| Jackfruit                           | <i>Artocarpus heterophyllus</i>                            | 13                | 85 to 90             |                            | Moderate                              | Moderate                          |                               | 2 to 4 weeks                 |   |
| Jerusalem artichoke                 | see Artichoke  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Jicama (yambean)                    | <i>Pachyrrhizus erosus</i>                                 | 13 to 18          | 85 to 90             |                            | Very low                              | Low                               | Low                           | 1 to 2 months                |   |
| Jujube (Chinese date)               | <i>Ziziphus jujuba</i>                                     | 2.5 to 10         | 85 to 90             | -1.6                       | Low                                   | Moderate                          |                               | 1 month                      |   |
| Kaki                                | see Persimmon  |                   |                      |                            |                                       |                                   |                               |                              |   |
| Kale                                | see Collards and kale                                      |                   |                      |                            |                                       |                                   |                               |                              |   |
| Kiwano                              | see African horned melon                                   |                   |                      |                            |                                       |                                   |                               |                              |   |
| Kiwifruit (Chinese gooseberry)      | <i>Actinidia chinensis</i>                                 | 0                 | 90 to 95             | -0.9                       | Low                                   | High                              | Low                           | 3 to 5 months                | 1 to 2% O <sub>2</sub><br>3 to 5% CO <sub>2</sub>   |
| Kohlrabi                            | <i>Brassica oleracea</i> var. <i>Gongylodes</i>            | 0                 | 98 to 100            | -1.0                       | Very low                              | Low                               | Low                           | 2 to 3 months                |   |
| Lo Bok                              | see Daikon   |                   |                      |                            |                                       |                                   |                               |                              |   |
| Langsat (lanzone)                   | <i>Aglaiia</i> sp.; <i>Lansium</i> sp.                     | 11 to 14          | 85 to 90             |                            |                                       |                                   |                               | 2 weeks                      |   |

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**Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (Continued)**

| Common Name<br>(Other Common Name)  | Scientific Name                                      | Storage Temp., °C | Relative Humidity, % | Highest Freezing Temp., °C | Ethylene Production Rate <sup>a</sup> | Ethylene Sensitivity <sup>b</sup> | Respiration Rate <sup>c</sup> | Approximate Postharvest Life | Observations and Beneficial CA <sup>d</sup> Conditions                               |
|-------------------------------------|--|-------------------|----------------------|----------------------------|---------------------------------------|-----------------------------------|-------------------------------|------------------------------|--|
| Leafy greens                        |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Cool-season                         | various  | 0                 | 95 to 100            | -0.6                       | Very low                              | High                              |                               | 10 to 14 days                |  |
| Warm-season                         | various  | 7 to 10           | 95 to 100            | -0.6                       | Very low                              | High                              |                               | 5 to 7 days                  |  |
| Leek                                | <i>Allium porrum</i>                                 | 0                 | 95 to 100            | -0.7                       | Very low                              | Moderate                          | Moderate                      | 2 months                     | 1 to 2% O <sub>2</sub><br>2 to 5% CO <sub>2</sub>                                    |
| Lemon                               | see Citrus   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Lettuce                             | <i>Lactuca sativa</i>                                | 0                 | 98 to 100            | -0.2                       | Very low                              | High                              | Low                           | 2 to 3 weeks                 | 2 to 5% O <sub>2</sub><br>0% CO <sub>2</sub>   |
| Lime                                | see Citrus   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Longan                              | <i>Dimocarpus longan</i><br>= <i>Euphoria longan</i> | 1 to 2            | 90 to 95             | -2.4                       |                                       |                                   |                               | 2 to 4 weeks                 |  |
| Loquat                              | <i>Eriobotrya japonica</i>                           | 0                 | 90                   | -1.9                       |                                       |                                   |                               | 3 weeks                      |  |
| Luffa (Chinese okra)                | <i>Luffa</i> spp.                                    | 10 to 12          | 90 to 95             |                            | Low                                   | Moderate                          |                               | 1 to 2 weeks                 |  |
| Lychee (litchi)                     | <i>Litchi chinensis</i>                              | 1 to 2            | 90 to 95             |                            | Moderate                              | Moderate                          | Low                           | 3 to 5 weeks                 | 3 to 5% O <sub>2</sub><br>3 to 5% CO <sub>2</sub>                                    |
| Malanga (tania, new cocoyam)        | <i>Xanthosoma sagittifolium</i>                      | 7                 | 70 to 80             |                            | Very low                              | Low                               |                               | 3 months                     |  |
| Mamey                               | see Sapotes  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Mandarin                            | see Citrus   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Mango                               | <i>Mangifera indica</i>                              | 13                | 85 to 90             | -1.4                       | Moderate                              | Moderate                          | Moderate                      | 2 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Mangosteen                          | <i>Garcinia mangostana</i>                           | 13                | 85 to 90             |                            | Moderate                              | High                              |                               | 2 to 4 weeks                 |  |
| Melons                              |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Cantaloupes and other netted melons | <i>Cucurbita melo</i> var. <i>reticulatus</i>        | 2 to 5            | 95                   | -1.2                       | High                                  | Moderate                          | Low                           | 2 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>10 to 15% CO <sub>2</sub>                                  |
| Casaba                              | <i>Cucurbita melo</i>                                | 7 to 10           | 85 to 90             | -1.0                       | Low                                   | Low                               |                               | 3 to 4 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Crenshaw                            | <i>Cucurbita melo</i>                                | 7 to 10           | 85 to 90             | -1.1                       | Moderate                              | High                              |                               | 2 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Honeydew, orange-flesh              | <i>Cucurbita melo</i>                                | 5 to 10           | 85 to 90             | -1.1                       | Moderate                              | High                              | Low                           | 3 to 4 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Persian                             | <i>Cucurbita melo</i>                                | 7 to 10           | 85 to 90             | -0.8                       | Moderate                              | High                              |                               | 2 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Mint                                | see Herbs  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Mombin                              | see Spondias   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Mushrooms                           | <i>Agaricus</i> , other genera                       | 0                 | 90                   | -0.9                       | Very low                              | Moderate                          | High                          | 7 to 14 days                 | 3 to 21% O <sub>2</sub><br>15 to 15% CO <sub>2</sub>                                 |
| Mustard greens                      | <i>Brassica juncea</i>                               | 0                 | 90 to 95             |                            | Very low                              | High                              |                               | 7 to 14 days                 |  |
| Nashi                               | see Asian pear                                       |                   |                      |                            |                                       |                                   |                               |                              |  |
| Nectarine                           | <i>Prunus persica</i>                                | -0.5 to 0         | 90 to 95             | -0.9                       | Moderate                              | Moderate                          | Low                           | 2 to 4 weeks                 | 1 to 2% O <sub>2</sub><br>3 to 5% CO <sub>2</sub><br>Internal breakdown at 3 to 10°C |
| Okra                                | <i>Abelmoschus esculentus</i>                        | 7 to 10           | 90 to 95             | -1.8                       | Low                                   | Moderate                          | High                          | 7 to 10 days                 | Air<br>4 to 10% CO <sub>2</sub>  |
| Olives, fresh                       | <i>Olea europea</i>                                  | 5 to 10           | 85 to 90             | -1.4                       | Low                                   | Moderate                          | Low                           | 4 to 6 weeks                 | 2 to 3% O <sub>2</sub><br>0 to 1% CO <sub>2</sub>                                    |
| Onion                               |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Mature bulbs, dry                   | <i>Allium cepa</i>                                   | 0                 | 65 to 70             | -0.8                       | Very low                              | Low                               | Low                           | 1 to 8 months                | 1 to 3% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Green                               | <i>Allium cepa</i>                                   | 0                 | 95 to 100            | -0.9                       | Low                                   | High                              | Moderate                      | 3 weeks                      | 2 to 4% O <sub>2</sub><br>10 to 20% CO <sub>2</sub>                                  |
| Orange                              | see Citrus   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Papaya                              | <i>Carica papaya</i>                                 | 7 to 13           | 85 to 90             | -0.9                       |                                       |                                   | Low                           | 1 to 3 weeks                 | 2 to 5% O <sub>2</sub><br>5 to 8% CO <sub>2</sub>                                    |
| Parsley                             | see Herbs  |                   |                      |                            |                                       |                                   |                               |                              |  |



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**Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (Continued)**

| Common Name<br>(Other Common Name)   | Scientific Name                                 | Storage Temp., °C | Relative Humidity, % | Highest Freezing Temp., °C | Ethylene Production Rate <sup>a</sup> | Ethylene Sensitivity <sup>b</sup> | Respiration Rate <sup>c</sup> | Approximate Postharvest Life | Observations and Beneficial CA <sup>d</sup> Conditions                               |
|--------------------------------------|---|-------------------|----------------------|----------------------------|---------------------------------------|-----------------------------------|-------------------------------|------------------------------|--|
| Parsnips                             | <i>Pastinaca sativa</i>                         | 0                 | 95 to 100            | -0.9                       | Very low                              | High                              | Low                           | 4 to 6 months                | Ethylene causes bitterness   |
| Passionfruit                         | <i>Passiflora</i> spp.                          | 10                | 85 to 90             |                            | Very high                             | Moderate                          | Very high                     | 3 to 4 weeks                 |  |
| Peach                                | <i>Prunus persica</i>                           | -0.5 to 0         | 90 to 95             | -0.9                       | High                                  | Moderate                          | Low                           | 2 to 4 weeks                 | 1 to 2% O <sub>2</sub><br>3 to 5% CO <sub>2</sub><br>Internal breakdown at 3 to 10°C |
| Pear, American <sup>e</sup>          | <i>Pyrus communis</i>                           | -1.5 to -0.5      | 90 to 95             | -1.7                       | High                                  | High                              | Low                           | 2 to 7 months                | Cultivar variations<br>1 to 3% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>             |
| Peas                                 |   |                   |                      |                            |                                       |                                   |                               |                              |  |
| In pods (snow, snap, and sugar peas) | <i>Pisum sativum</i>                            | 0 to 1            | 90 to 98             | -0.6                       | Very low                              | Moderate                          | Very high                     | 1 to 2 weeks                 | 2 to 3% O <sub>2</sub><br>2 to 3% CO <sub>2</sub>                                    |
| Southern peas (cowpeas)              | <i>Vigna sinensis</i> = <i>V. unguiculata</i>   | 4 to 5            | 95                   |                            |                                       |                                   |                               | 6 to 8 days                  |  |
| Pepino (melon pear)                  | <i>Solanum muricatum</i>                        | 5 to 10           | 95                   |                            | Low                                   | Moderate                          |                               | 4 weeks                      |  |
| Peppers                              |   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Bell pepper or paprika               | <i>Capsicum annuum</i>                          | 7 to 10           | 95 to 98             | -0.7                       | Low                                   | Low                               | Low                           | 2 to 3 weeks                 | 2 to 5% O <sub>2</sub><br>2 to 5% CO <sub>2</sub>                                    |
| Hot peppers (chiles)                 | <i>Capsicum annuum</i> and <i>C. frutescens</i> | 5 to 10           | 85 to 95             | -0.7                       | Low                                   | Moderate                          |                               | 2 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Persimmon (kaki)                     | <i>Dispyros kaki</i>                            |                   |                      |                            |                                       |                                   |                               |                              | 3 to 5% O <sub>2</sub><br>5 to 8% CO <sub>2</sub>                                    |
| Fuyu                                 | <i>Dispyros kaki</i> var. <i>Fuyu</i>           | 0                 | 90 to 95             | -2.2                       | Low                                   | High                              | Low                           | 1 to 3 months                |  |
| Hachiya                              | <i>Dispyros kaki</i> var. <i>Hachiya</i>        | 0                 | 90 to 95             | -2.2                       | Low                                   | High                              | Low                           | 2 to 3 months                |  |
| Pineapple                            | <i>Ananas comosus</i>                           | 7 to 13           | 85 to 90             | -1.1                       | Low                                   | Low                               | Low                           | 2 to 4 weeks                 | 2 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| Plantain                             | <i>Musa paradisiaca</i> var. <i>paradisiaca</i> | 13 to 15          | 90 to 95             | -0.8                       | Low                                   | High                              |                               | 1 to 5 weeks                 |  |
| Plums and prunes                     | <i>Prunus domestica</i>                         | -0.5 to 0         | 90 to 95             | -0.8                       | Moderate                              | Moderate                          | Low                           | 2 to 5 weeks                 | 1 to 2% O <sub>2</sub><br>0 to 5% CO <sub>2</sub>                                    |
| Pomegranate                          | <i>Punica granatum</i>                          | 5                 | 90 to 95             | -3.0                       |                                       |                                   | Low                           | 2 to 3 months                | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>                                   |
| <b>Potato</b>                        |   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Early crop                           | <i>Solanum tuberosum</i>                        | 10 to 15          | 90 to 95             | -0.8                       | Very low                              | Moderate                          | Low                           | 10 to 14 days                | No CA benefit  |
| Late crop                            | <i>Solanum tuberosum</i>                        | 4 to 12           | 95 to 98             | -0.8                       | Very low                              | Moderate                          | Low                           | 5 to 10 months               | No CA benefit  |
| Pumpkin                              | <i>Cucurbita maxima</i>                         | 12 to 15          | 50 to 70             | -0.8                       | Very low                              | Moderate                          | Low                           | 2 to 3 months                |  |
| Quince                               | <i>Cydonia oblonga</i>                          | -0.5 to 0         | 90                   | -2.0                       | Low                                   | High                              |                               | 2 to 3 months                |  |
| Raddichio                            | <i>Cichorium intybus</i>                        | 0 to 1            | 95 to 100            |                            |                                       |                                   |                               | 4 to 8 weeks                 |  |
| Radish                               | <i>Raphanus sativus</i>                         | 0                 | 95 to 100            | -0.7                       | Very low                              | Low                               | Low                           | 1 to 2 months                | 1 to 2% O <sub>2</sub><br>2 to 3% CO <sub>2</sub>                                    |
| Rambutan                             | <i>Nephelium lappaceum</i>                      | 12                | 90 to 95             |                            | High                                  | High                              |                               | 1 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>7 to 12% CO <sub>2</sub>                                   |
| Rhubarb                              | <i>Rheum rhaponticum</i>                        | 0                 | 95 to 100            | -0.9                       | Very low                              | Low                               | Low                           | 2 to 4 weeks                 |  |
| Rutabaga                             | <i>Brassica napus</i> var. <i>Napobrassica</i>  | 0                 | 98 to 100            | -1.1                       | Very low                              | Low                               | Low                           | 4 to 6 months                |  |
| Sage                                 | see Herbs                                       |                   |                      |                            |                                       |                                   |                               |                              |  |
| Salsify (vegetable oyster)           | <i>Trapopogon porrifolius</i>                   | 0                 | 95 to 98             | -1.1                       | Very low                              | Low                               | Low                           | 2 to 4 months                |  |
| Sapotes                              |   |                   |                      |                            |                                       |                                   |                               |                              |  |
| Black sapote                         | <i>Diospyros ebenaster</i>                      | 13 to 15          | 85 to 90             | -2.3                       |                                       |                                   |                               | 2 to 3 weeks                 |  |
| Caimito (star apple)                 | <i>Chrysophyllum cainito</i>                    | 3                 | 90                   | -1.2                       |                                       |                                   |                               | 3 weeks                      |  |
| Canistel (eggfruit)                  | <i>Pouteria campechiana</i>                     | 13 to 15          | 85 to 90             | -1.8                       |                                       |                                   |                               | 3 weeks                      |  |

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**Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (Continued)**

| Common Name<br>(Other Common Name)         | Scientific Name  | Storage Temp., °C | Relative Humidity, % | Highest Freezing Temp., °C | Ethylene Production Rate <sup>a</sup> | Ethylene Sensitivity <sup>b</sup> | Respiration Rate <sup>c</sup> | Approximate Postharvest Life | Observations and Beneficial CA <sup>d</sup> Conditions |
|--|--|-------------------|----------------------|----------------------------|---------------------------------------|-----------------------------------|-------------------------------|------------------------------|--|
| Mamey sapote                               | <i>Calocarpum mammosum</i>                             | 13 to 15          | 90 to 95             |                            | High                                  | High                              |                               | 2 to 3 weeks                 |  |
| Sapodilla (chicosapote)                    | <i>Achras sapota</i>                                   | 15 to 20          | 85 to 90             |                            | High                                  | High                              |                               | 2 weeks                      |  |
| White sapote                               | <i>Casimiroa edulis</i>                                | 20                | 85 to 90             | -2.0                       |                                       |                                   |                               | 2 to 3 weeks                 |  |
| Scorzonera                                 | see Black salsify                                      |                   |                      |                            |                                       |                                   |                               |                              |  |
| Shallot                                    | <i>Allium cepa</i> var. <i>ascalonicum</i>             | 0 to 2.5          | 65 to 70             | -0.7                       | Low                                   | Low                               |                               |                              |  |
| Soursop                                    | <i>Annona muricata</i>                                 | 13                | 85 to 90             |                            |                                       |                                   |                               | 1 to 2 weeks                 |  |
| Spinach                                    | <i>Spinacia oleracea</i>                               | 0                 | 95 to 100            | -0.3                       | Very low                              | High                              | Low                           | 10 to 14 days                | 5 to 10% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>    |
| Spondias (mombin, wi apple, jobo, hogplum) | <i>Spondias</i> spp.                                   | 13                | 85 to 90             |                            |                                       |                                   |                               | 1 to 2 weeks                 |  |
| Sprouts from seeds                         |  | 0                 | 95 to 100            |                            |                                       |                                   |                               | 5 to 9 days                  |  |
| Alfalfa sprouts                            | <i>Medicago sativa</i>                                 | 0                 | 95 to 100            |                            |                                       |                                   |                               | 7 days                       |  |
| Bean sprouts                               | <i>Phaseolus</i> sp.                                   | 0                 | 95 to 100            |                            |                                       |                                   |                               | 7 to 9 days                  |  |
| Radish sprouts                             | <i>Raphanus</i> sp.                                    | 0                 | 95 to 100            |                            |                                       |                                   |                               | 5 to 7 days                  |  |
| Squash                                     |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Summer, soft rind (courgette)              | <i>Cucurbita pepo</i>                                  | 7 to 10           | 95                   | -0.5                       | Low                                   | Moderate                          | Low                           | 1 to 2 weeks                 | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>     |
| Winter, hard rind (calabash)               | <i>Cucurbita moschata</i> ; <i>C. maxima</i>           | 12 to 15          | 50 to 70             | -0.8                       | Low                                   | Moderate                          | Low                           | 2 to 3 months                | Large differences among varieties                      |
| Star apple                                 | see Sapotes  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Starfruit                                  | see Carambola  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Sweet potato or yam                        | <i>Ipomea batatas</i>                                  | 13 to 15          | 85 to 95             | -1.3                       | Very low                              | Low                               | Low                           | 4 to 7 months                |  |
| Sweetsop (sugar apple, custard apple)      | <i>Annona squamosa</i> ; <i>Annona</i> spp.            | 7                 | 85 to 90             |                            | High                                  | High                              |                               | 4 weeks                      | 3 to 5% O <sub>2</sub><br>5 to 10% CO <sub>2</sub>     |
| Tamarillo (tree tomato)                    | <i>Cyphomandra betacea</i>                             | 3 to 4            | 85 to 95             |                            | Low                                   | Moderate                          |                               | 10 weeks                     |  |
| Tamarind                                   | <i>Tamarindus indica</i>                               | 2 to 7            | 90 to 95             | -3.7                       | Very low                              | Very Low                          |                               | 3 to 4 weeks                 |  |
| Taro (cocoyam, eddoe, dasheen)             | <i>Colocasia esculenta</i>                             | 7 to 10           | 85 to 90             | -0.9                       |                                       |                                   | Low                           | 4 months                     | No CA benefit  |
| Thyme                                      | see Herbs  |                   |                      |                            |                                       |                                   |                               |                              |  |
| Tomatillo (husk tomato)                    | <i>Physalis ixocarpa</i>                               | 7 to 13           | 85 to 90             |                            | Very low                              | Moderate                          | Low                           | 3 weeks                      |  |
| <b>Tomato</b>                              |  |                   |                      |                            |                                       |                                   |                               |                              |  |
| <b>Mature, green</b>                       | <i>Lycopersicon esculentum</i>                         | 10 to 13          | 90 to 95             | -0.5                       | Very low                              | High                              | Low                           | 2 to 5 weeks                 | 3 to 5% O <sub>2</sub><br>2 to 3% CO <sub>2</sub>      |
| <b>Firm, ripe</b>                          | <i>Lycopersicon esculentum</i>                         | 8 to 10           | 85 to 90             | -0.5                       | High                                  | Low                               | Low                           | 1 to 3 weeks                 | 3 to 5% O <sub>2</sub><br>3 to 5% CO <sub>2</sub>      |
| Turnip root                                | <i>Brassica campestris</i> var. <i>Rapifera</i>        | 0                 | 95                   | -1.0                       | Very low                              | Low                               | Low                           | 4 to 5 months                |  |
| Water chestnut                             | <i>Eleocharis dulcis</i>                               | 1 to 2            | 85 to 90             |                            |                                       |                                   |                               | 2 to 4 months                |  |
| Watercress (garden cress)                  | <i>Lepidium sativum</i> ; <i>Nasturtium officinale</i> | 0                 | 95 to 100            | -0.3                       | Very low                              | High                              | High                          | 2 to 3 weeks                 |  |
| Watermelon                                 | <i>Citrullus vulgaris</i>                              | 10 to 15          | 90                   | -0.4                       | Very low                              | High                              | Low                           | 2 to 3 weeks                 | No CA benefit  |
| Yam  | <i>Dioscorea</i> spp.                                  | 15                | 70 to 80             | -1.1                       | Very low                              | Low                               |                               | 2 to 7 months                |  |
| Yucca                                      | see Cassava  |                   |                      |                            |                                       |                                   |                               |                              |  |

Note: Recommendations in this table are general guidelines. Recommended storage conditions and expected postharvest life for a specific produce item may be different from those listed here because of variations in growing conditions and postharvest care. Also, new cultivars (varieties) of a particular item may require different conditions and have a very different expected postharvest life from that listed in the table. Empty cells indicate that no data are available. For updates on guidelines, refer to the University of California Web site at <http://postharvest.ucdavis.edu>.

<sup>a</sup> Very low = <0.1  $\mu\text{L}/(\text{kg} \cdot \text{h})$  at 20°C  
Low = 0.1 to 1.0  $\mu\text{L}/(\text{kg} \cdot \text{h})$   
Moderate = 1.0 to 10.0  $\mu\text{L}/(\text{kg} \cdot \text{h})$   
High = 10 to 100  $\mu\text{L}/(\text{kg} \cdot \text{h})$   
Very high = >100  $\mu\text{L}/(\text{kg} \cdot \text{h})$

<sup>b</sup> Detrimental effects include yellowing, softening, increased decay, abscission, and browning.  
<sup>c</sup> At recommended storage temperature.  
Low = <20 mg CO<sub>2</sub>/(kg · h)  
Moderate = <40 mg CO<sub>2</sub>/(kg · h)  
High = <60 mg CO<sub>2</sub>/(kg · h)  
Very high = >60 mg CO<sub>2</sub>/(kg · h)  
<sup>d</sup> CA = controlled atmosphere.



# End mission report Kassala cold room project

## **Description of preliminary meetings with actors**

As this is a pilot project, solutions were evaluated that could guarantee the greatest possible flexibility of use. Taking into account the location of the cell itself. In a geographical area with important climatic criticalities. Not only because of the temperature and humidity of the environment, but also because the sand, always present and carried by the wind, but also of the rain that falls abundantly in some periods of the year. In particular from August to October.

After an exchange of preliminary e-mails with Dr. Mirco Abbondanza of AICS and Dr. Marco Azzalini of UNIDO to define the characteristics of the cold room such as: geographic macro position, dimensions, products to be stored, several preliminary meetings were held with manufacturing companies of cold storage and accessories. These meetings served to gather all the necessary documentation to start the feasibility study according to the needs of the project and to be able to evaluate any subsequent enlargement.

After obtaining the aforementioned material in Italy, we moved to Khartoum where some in-depth meetings were held with the AICS and UNIDO actors already mentioned.

Then we moved to Kassala to start the study on the field.

Meetings were held with the managers of the Al Ikhaa Cooperative. They have expressed their needs, however, in line with the ideas already gathered through the previous meetings held. They also indicated some geographic areas on which to build the cold storage.

The positions indicated were two. The first one, even if well served by water and electricity, was difficult to reach as it had a particularly disadvantaged road.

While the second position indicated has received everyone's approval. In addition to water, electricity and located in a central position with respect to the city. Also enlaved by different roads all asphalted and in good condition.

Below is the Google Earth link and some aerial photos of the cold store construction area.

Link:

<https://earth.app.goo.gl/?apn=com.google.earth&ibi=com.google.b612&isi=293622097&ius=googleearth&link=https%3a%2f%2fearth.google.com%2fweb%2f%4015.45254136,36.36995525,505.38977287a,399.07677307d,35y,0h,0t,0r>

## End mission report Kassala cold room project



Photo 1

## End mission report Kassala cold room project



Photo 2



# End mission report Kassala cold room project

In the first image you can see the macroposition with the various access roads, while in the second picture the area on which the parties want to build the cold room and install the machines is shown in purple.

The only criticality found is the ownership of the land. In fact, the government is the owner of the land.

To find a solution to this problem and also to have a confrontation with local authorities, an agreement was set up between the ministry of agriculture, the Al Ikhaa cooperative, AICS and UNIDO.

During the meeting the proposals and motivations for which we were directed towards a specific sizing and the technical characteristics of the cold storage were exposed. The arguments were well received and accepted by both the ministry and the cooperative.

Therefore, in light of this, it was decided to proceed by also implementing changes that emerged during the meeting. The ministry has also pledged to find an agreement with the government to grant the land on which to build the cold store.

# End mission report Kassala cold room project

## **Cold storage technical description**

### **Layout respects the sun:**

Assuming that the layout on the ground must take into account the best possible orientation, to date it is believed that an exposure north, north-west of the front may be the best solution.

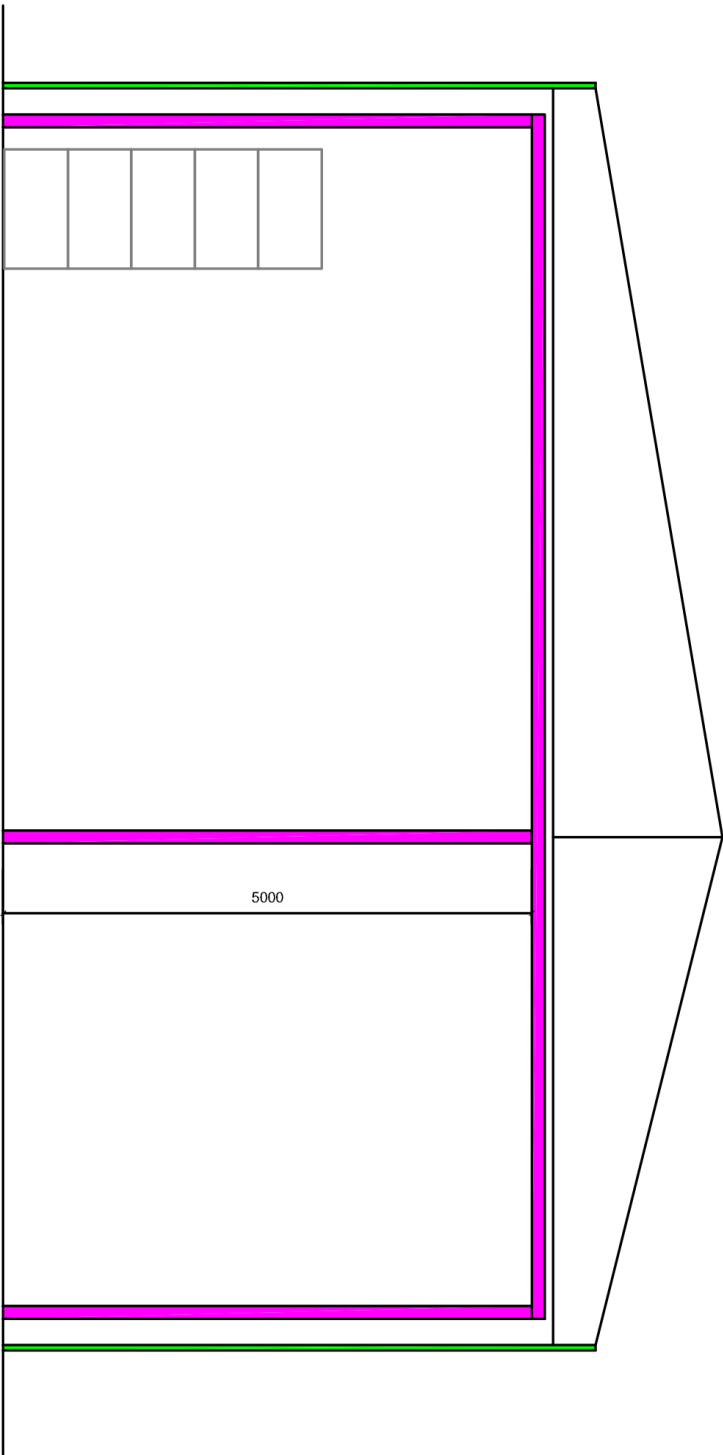
### **Technical point:**

The following is a technical description of how to proceed with the production of the cold room and the necessary components for its correct operation.

To better understand, a simplified introductory drawing is inserted below.

(It will also be attached in A3 format)

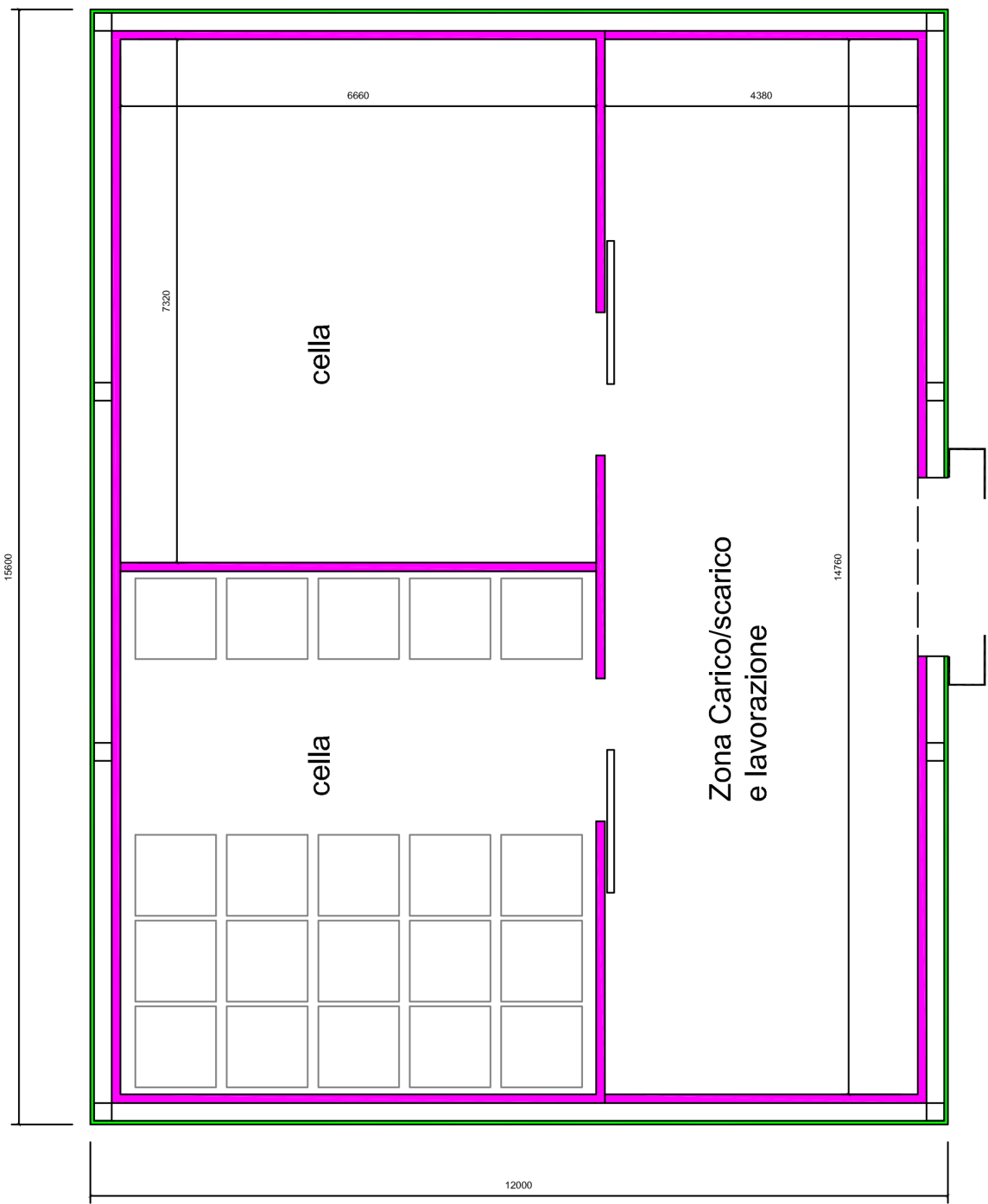
End mission report Kassala cold room project



Front view



End mission report Kassala cold room project



Top view

# End mission report Kassala cold room project

## External structure:

As can be seen from the drawings, the cell will be installed inside a structure made of mixed masonry and metallic carpentry. The definitive measures have not yet been defined, therefore the values expressed are to be considered indicative.

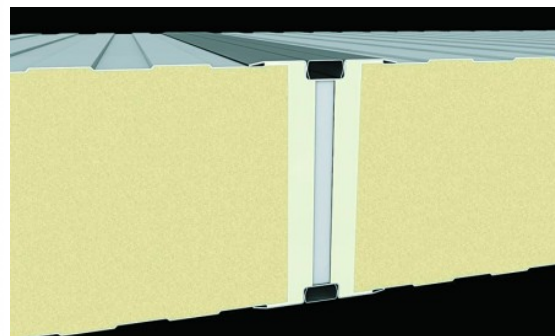
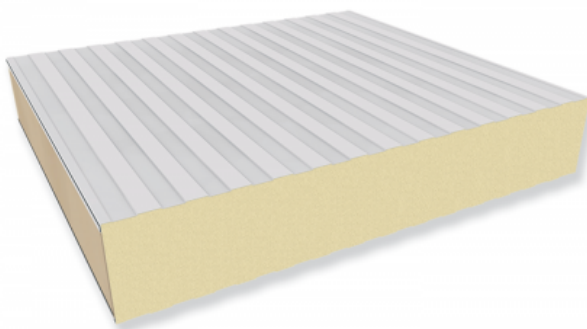
The external building will be composed perimetrically, up to a height of 3 meters of bricks arranged appropriately to make sure that there is circulation of air from the bottom upwards. The upper part of the perimeter, up to the area of the roof beams will be made of sandwich panels in polyurethane.

The roof will also be made of polyurethane panels. In this case, load-bearing panels will be used, the load of which will be defined in the dimensional calculation and in accordance with the regulations in force in the country of construction. The top of the roof will have an opening to allow the hot air to escape thus creating an extraction effect (natural fireplace).

This structure around the cell is necessary because of the high temperatures that are reached during the day. In this way the energy requirements of the cold room can be reduced by about 35%. To the advantage of the cost of management and maintenance.

Anti-sand net will be inserted perimeter to reduce infiltration between the interspaces as much as possible. The perimeter panels will have a slatted structure. While the thickness will be variable between 150-200 mm. The greater thickness will be used in the areas most exposed to the sun.

Below photos as an example:

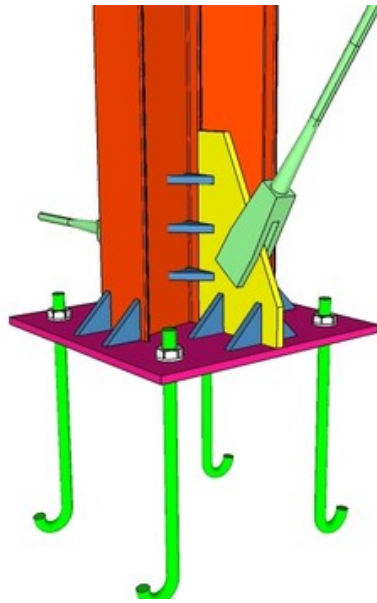


Slatwall panels

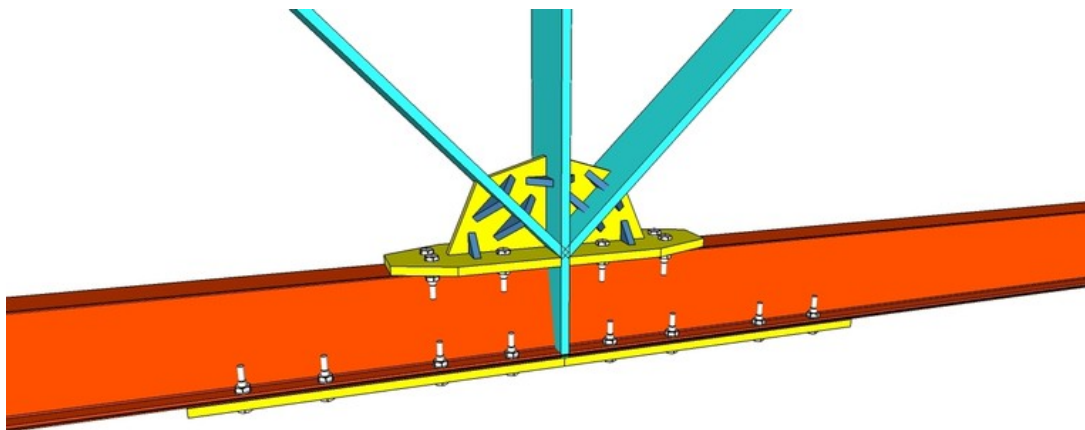
# End mission report Kassala cold room project

The roof panels will also be sandwiched with polyurethane insulation. The roof panels will also be sandwiched with polyurethane insulation. As already written, we are waiting to give the dimensions after having carried out the necessary structural calculation. It is recommended to use a corrugated panel, as it is safer to walk on and slippery, when maintenance workers have to climb on it. As an indication of thickness, it can already be stated that it should not be less than 120 mm. This is due to exposure to sunlight and to heavy rain that falls during the rainy season. The external structure will also act as coverage of the area defined for sorting and first screening of incoming goods.

Below are some pictures of how the structure will be built:

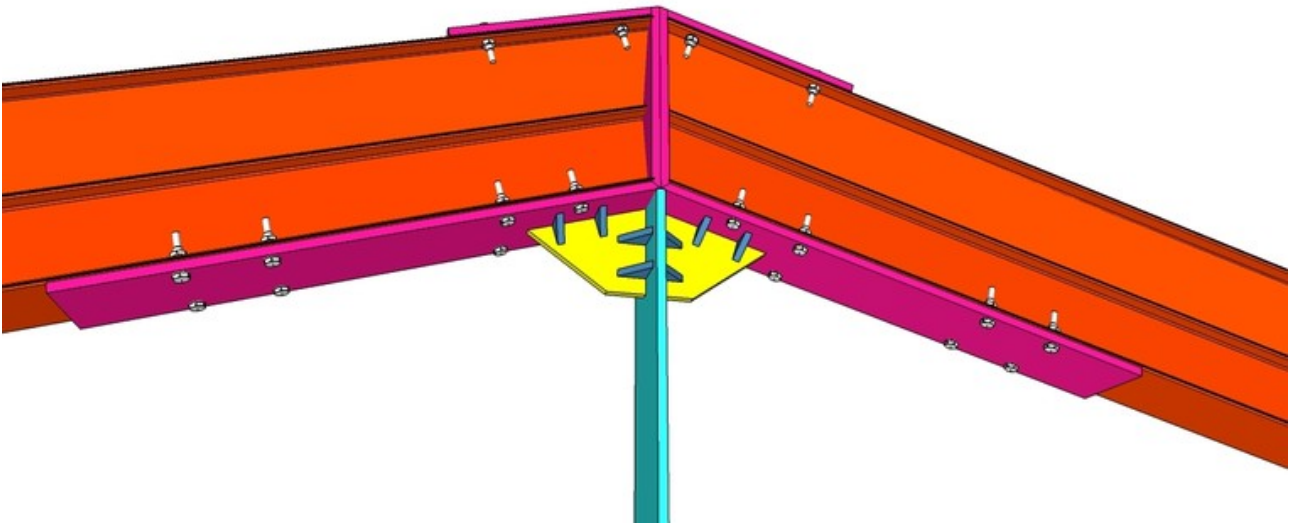


Fixing to the base with bolts

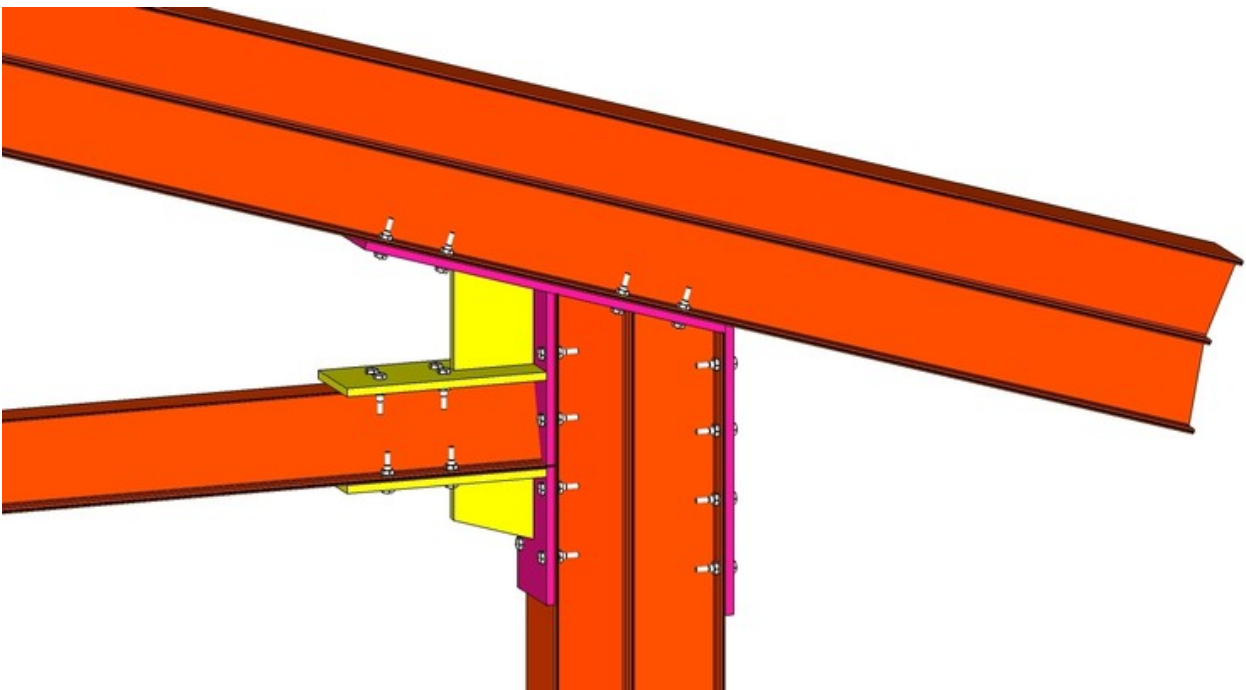


Fixing beams

## End mission report Kassala cold room project

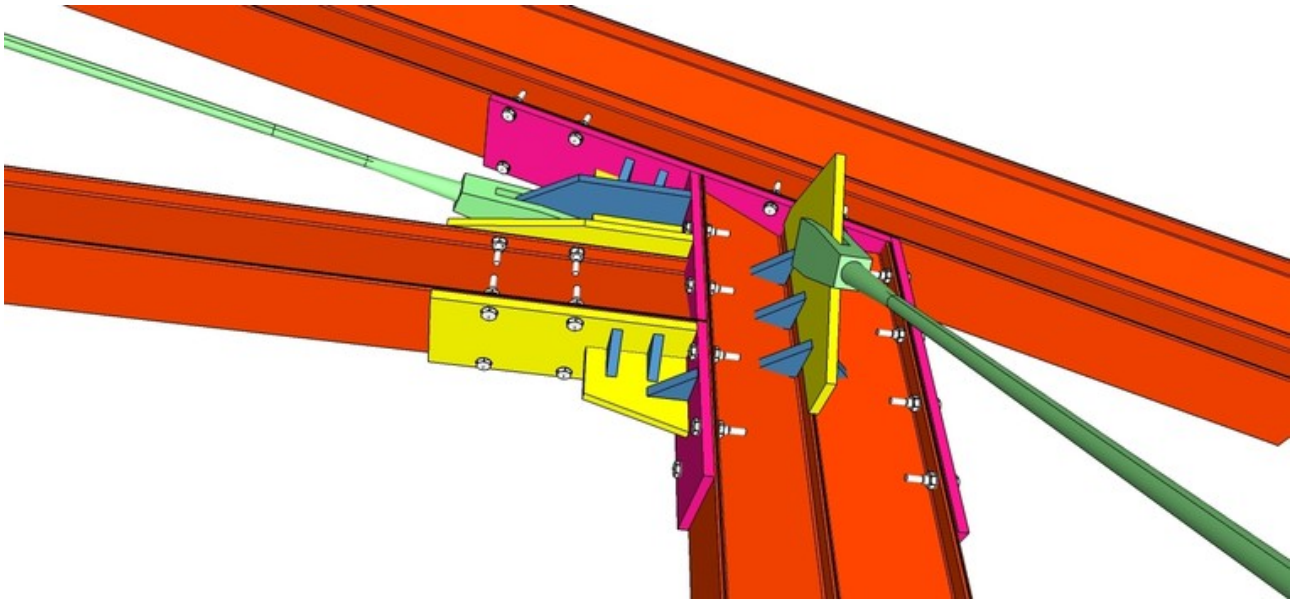


Fixing load-bearing pillars and roof beams

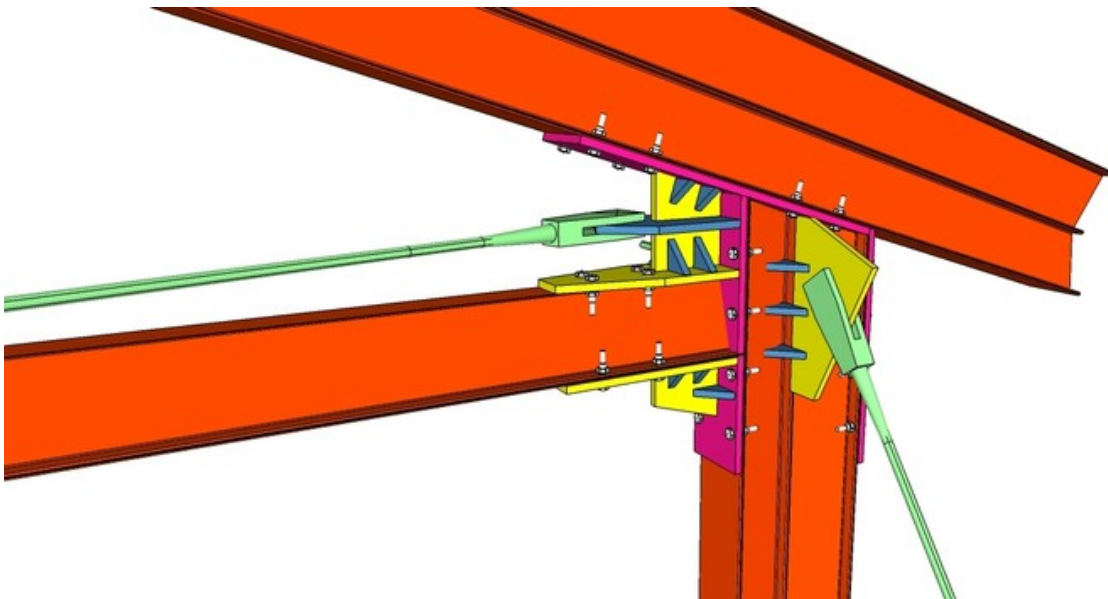


Fixing side and upper beams to the roof

## End mission report Kassala cold room project

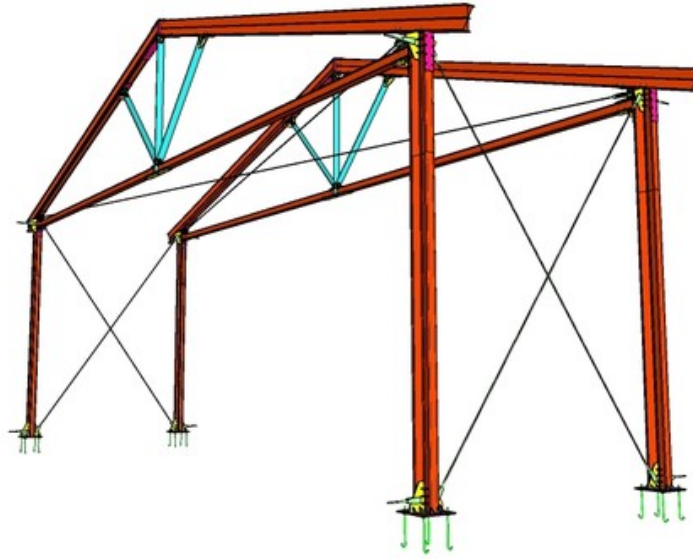


Fixing roof beams with tie rods

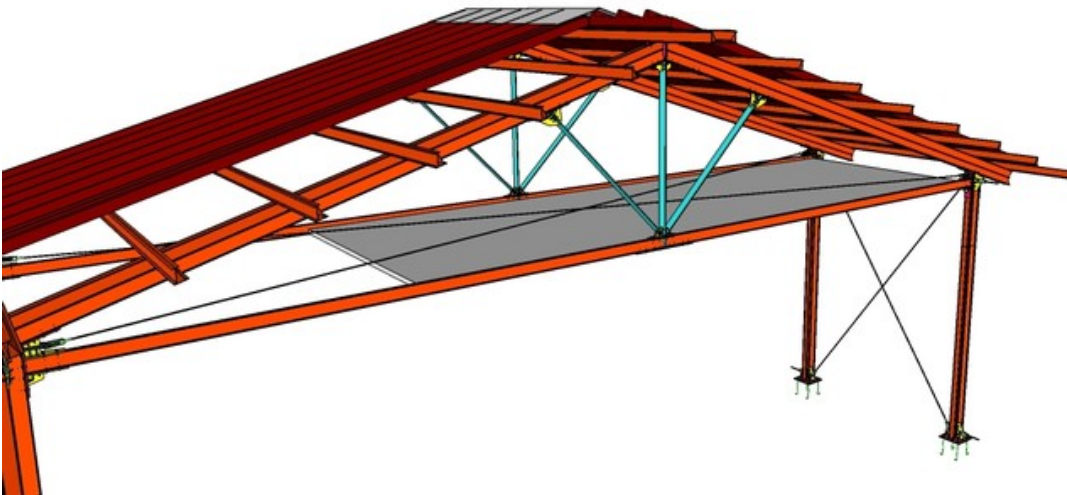


Roof fixing with side and upper tie-rods

## End mission report Kassala cold room project



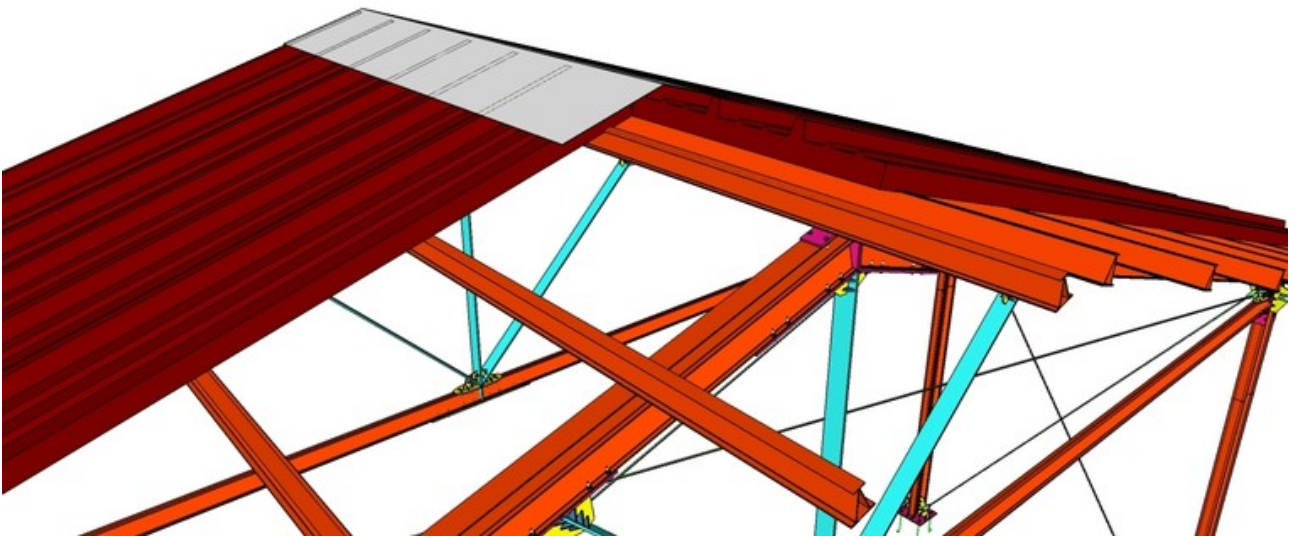
Overall drawing of vertical beams and roof



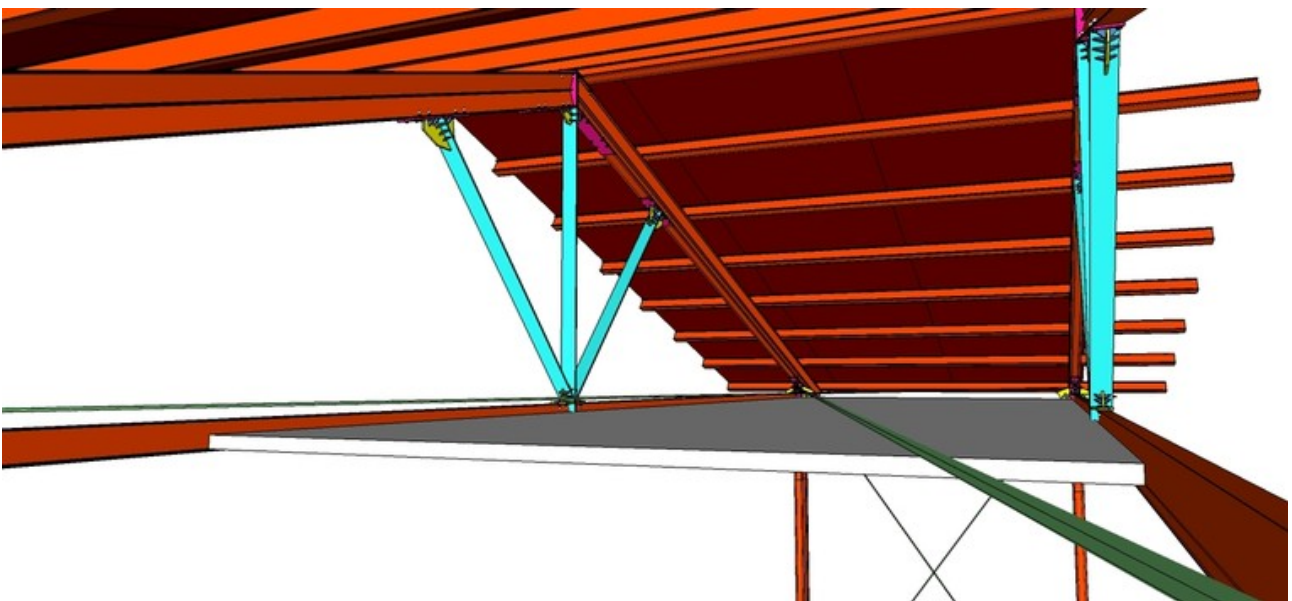
Front view of the roof structure



## End mission report Kassala cold room project



Roof top view

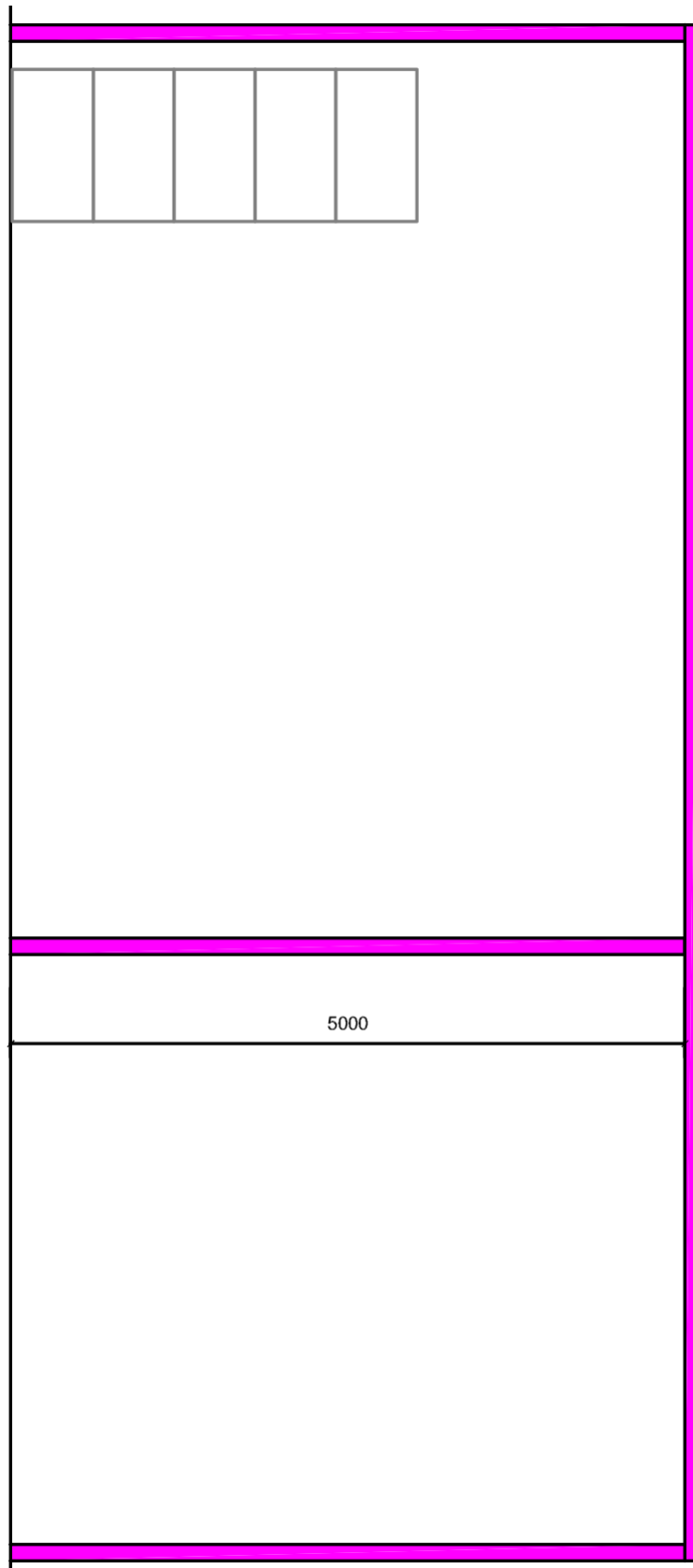


View of supporting beams

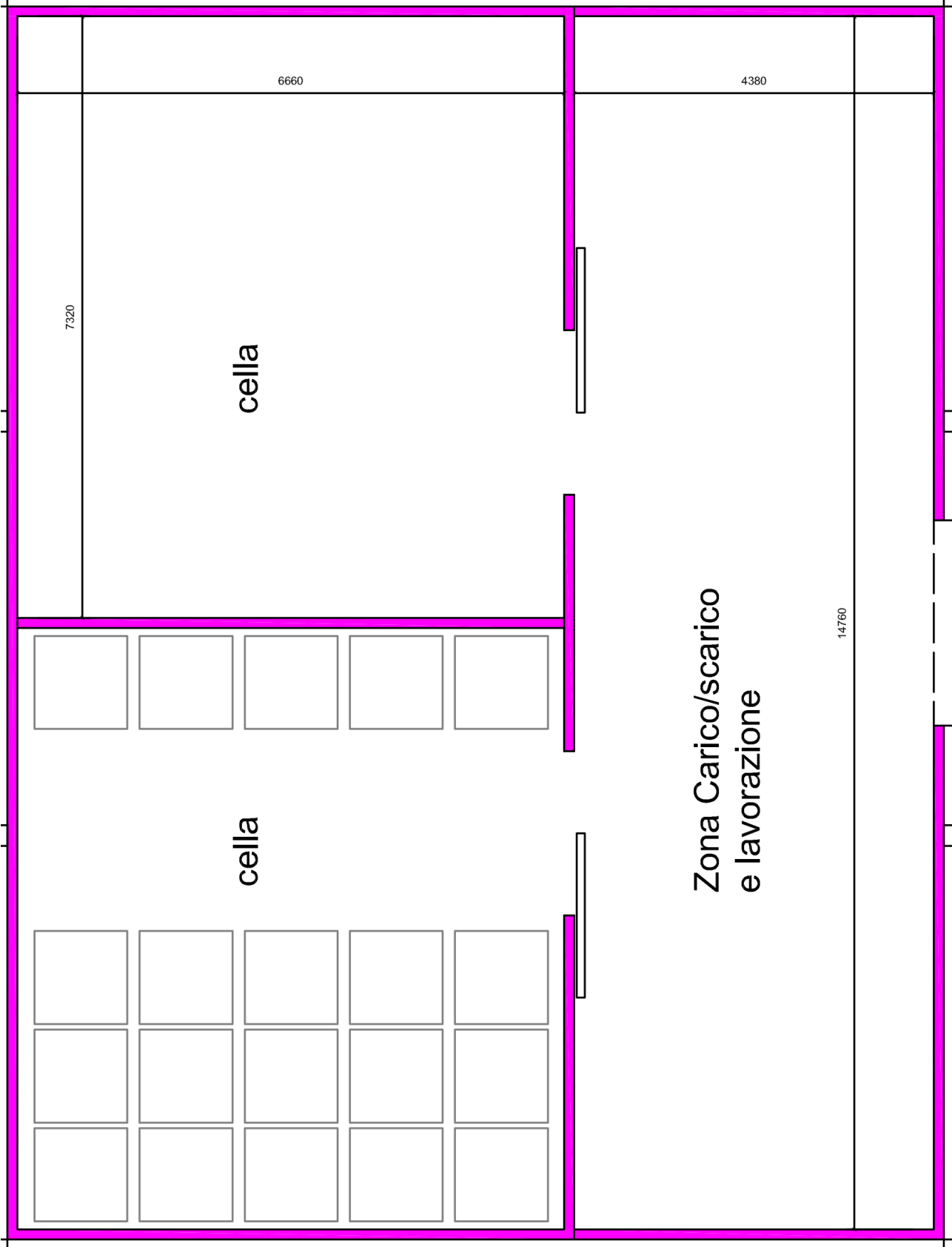
# End mission report Kassala cold room project

## Cold room:

Also for this section of the report drawings are inserted to better clarify the ideas and the nodal points of the project



End mission report Kassala cold room project



# End mission report Kassala cold room project

It will be divided into three areas, two will be specific cold rooms. The third area, which will benefit from a different refrigeration, will be used for loading / unloading and processing of goods. Both incoming goods and departing goods.

The fridge cells will have the following dimensions:

- Length 7.20 meters
- 6.60 meters width
- Height 5.00 meters. Thus obtaining an internal surface of 47.52 square meters and a cubage of: 237.60 cubic meters each cell.

The central dividing wall will be realized on mobile slides so as to be able to vary the internal volume according to the quantity of material to be stored.

Obviously, minimum cubic values must be defined for each cell that will take into account the input ports and the refrigeration compressors. In order to avoid the crisis of cooling systems.

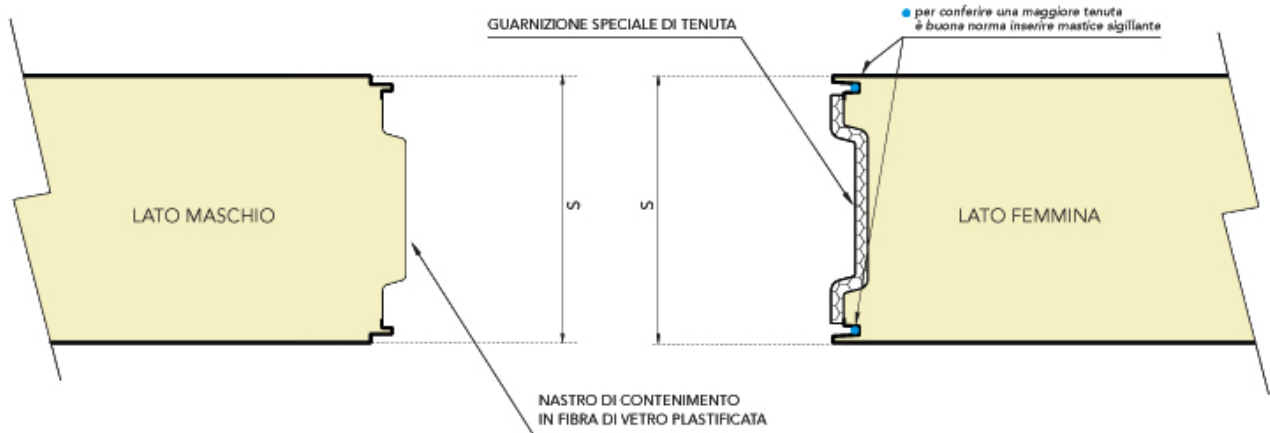
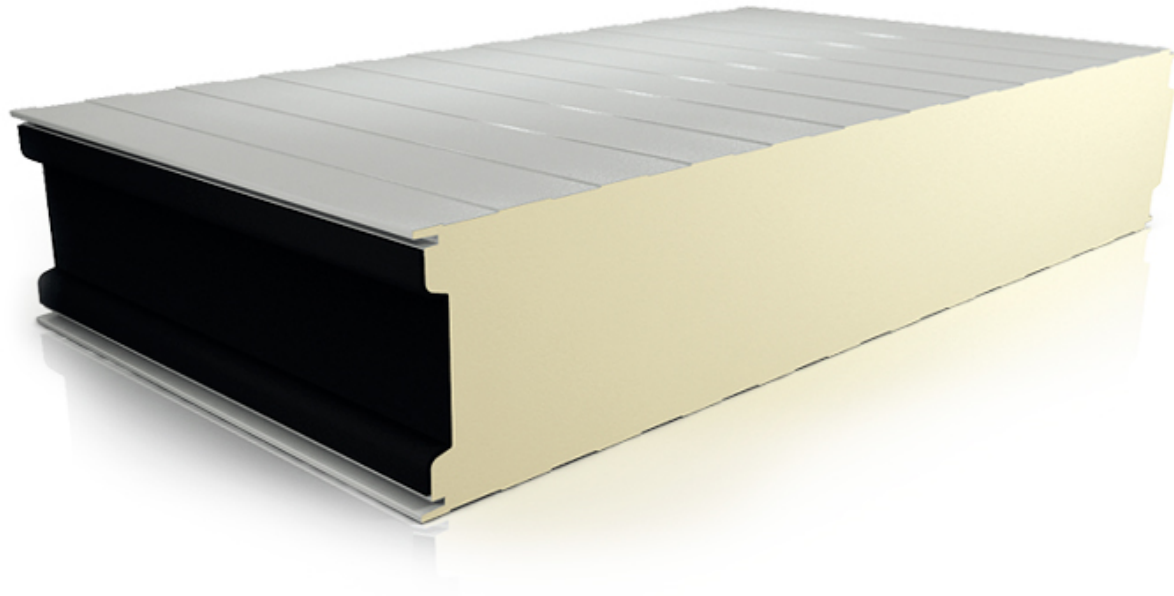
The possibility of having cells with a controlled environment has been requested, and this is a critical point from the point of view of safety, since the controlled atmosphere systems also provide for the introduction of N (nitrogen) inside them, deadly gas in high concentration, it was decided to realize a single cell with gas supply systems and implement all the security checks necessary for the correct operation of the same. Furthermore, a specific course must be carried out to operators on the correct use of the cell in question and which are the correct safety rules to follow. On this point there cannot be exceptions, given the danger.

For the correct and orderly insertion of the products inside, caissons will be provided that will have approximately 1x1x 0.60 meters and can be moved with transpalletts or forklifts. By examining the cells with division in the middle of the mobile inner wall, 100 boxes can be housed inside each cell. As you can easily see from the drawings. A corridor must be left at the doors to move the goods inside. Furthermore, a space must be left between the goods and the ceiling of 1 meter to allow the evaporators to work.

The cell structure will be made of self-extinguishing 200 mm thickness polyurethane panels.

# End mission report Kassala cold room project

Below are some sample photos:



# End mission report Kassala cold room project

For the ceiling the same panels will be used, but with reinforced structure to allow the housing of the evaporators.

See photos as an example:



Ceiling evaporator

## **Electrical system and lighting:**

The electrical system will be sized for each refrigerator cell module and will include the use of self-extinguishing cables, differential switches, magneto-thermal switches dimensioned to specific use. Selected brands will be chosen also in Sudan, in order to avoid problems of material procurement during both ordinary and extraordinary maintenance.

For the lighting will be provided thin LED panels with 6000 ° K cold white light. They will be arranged in line and can be switched on and off depending on the needs of the cells and where the movable central wall will be located. Each series of switches will be positioned outside the cells, in a position to be defined. Ergonomic evaluations will be made in the final design phase.

The cells will be equipped with presence sensors, to avoid that the doors can be closed involuntarily with personnel still inside.

Any further definition of the plant will be carried out later, in compliance with the regulations in the host country of the project.



# End mission report Kassala cold room project

## **Basement:**

The base on which the entire structure will be built will have to be built in a stratified way and will be composed as follows, starting from the lower section:

- Overflow gravel
- Lean concrete. Mixed gravel cement
- Insulating material (rock wool or polyurethane panels)
- Walkable concrete floor reinforced with metallic net (8mm)
- Cement finish with polishing
- Painting with antibacterial resin

## **Refrigerating unit:**

The cooling system provides two units that can serve the cells at the same time and can also be put into operation independently in case of specific needs. However, two units are also planned to simplify the weekly maintenance operations. During the course of the aforementioned operations, one group may be switched off and the other kept in operation for the required time.

*The thermal powers are still being defined.*

## **Generator set and voltage stabilizer:**

During the inspection in Kassala there were frequent lack of electricity and variations in the supply of electricity. Possible causes of malfunction and breakage of electrical components of the cold store. Therefore a generator is foreseen which will be sized later. It will be equipped with anti-noise cover, tropicalisation and automatic changeover.

Furthermore, it is recommended to insert an appropriately sized voltage stabilizer. (See document in attachment)

# End mission report Kassala cold room project

## **Conclusions:**

This report is intended to be the introductory part to what will be the definitive and design report of the cold storage and the other components that will constitute it. It is considered necessary a further mission to consolidate the contacts made with the local authorities and with all the suppliers, also local, able to finalize the project. Being a nation with important problems concerning the electricity and water supply, simple, but effective solutions must be studied in order to have an adequate functioning of the cold room. We want to spend two last words on the water supply, a topic that was not dealt with previously in the report.

This is because to date there is still no reliable data on how the water supporting the cold room will be used. If only to wash the outside or even to treat fruit and vegetables and also for internal washing of the cold storage. In this case, bacteria filtration and abatement systems must be provided, using biological sand filters and UV lamps.