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EU NIGHT WIND Project



SIXTH FRAMEWORK
PROGRAMME

GRID ARCHITECTURE FOR WIND POWER PRODUCTION WITH ENERGY STORAGE THROUGH LOAD SHIFTING IN REFRIGERATED WAREHOUSES

WORK PACKAGE 4: *FOOD QUALITY*

QUALITY ATTRIBUTES OF FROZEN FOODS UNDERGOING TEMPERATURE FLUCTUATIONS (FREEZE-THAW CYCLES): *EXTRACT FROM EXPERIMENTAL DATA*

Parallel tests have been conducted with 10 different food samples of identical type, shape and size, stored during 8 months at constant and variable temperature regimes. The samples – meat (bacon), fish (smoked Mackerel fillet), bakeries (fruit pie), fruit (strawberries), vegetables (tomatoes, melons and peppers), potatoes (blanched/semi-grilled French fries) and ice cream have been wrapped in plastic bags and boxes, evacuated and frozen at a constant air temperature of $-19\text{ }^{\circ}\text{C}$ as well as at a variable temperature (with day-night cycles) ranging from $-16/-18\text{ }^{\circ}\text{C}$ down to $-26/-28\text{ }^{\circ}\text{C}$.

After 3 days, and 2, 4, 6 and 8 months of frozen storage, the samples have been thawed in air ambience up to a temperature in the product centre of $20-22\text{ }^{\circ}\text{C}$. Thus, a number of quality attributes have periodically been evaluated – texture (by penetrometric measurements), colour (by the method of Gardner) and drip losses. Sensory evaluation has also been carried out (with the aid of a taste panel) to estimate the product appearance, colour, flavour and consistency.

The obtained data revealed that quality attributes of foods stored in frozen state at a variable temperature regime (involving freeze-thaw cycles) are comparable but generally inferior than the attributes of products maintained frozen at a constant temperature with no substantial temperature fluctuations. For instance, perceptible differences in the average sensory attributes (colour of meat, melons, tomatoes, peppers and strawberries; texture of meat, fish, melons, tomatoes, peppers, potatoes; flavour of Sivria pepper and raspberries; appearance of tomatoes, peppers, strawberries and fruit pie) have been detected even in the very beginning of the storage

period (after 3 days of storage). The sensory attributes of all products stored at the variable regime during a four-month period are also slightly deteriorated as compared with the identical products kept at a constant temperature of frozen storage.

Statistically significant undesirable differences between the two regimes are detected in the average texture values for all vegetables studied, strawberries, fruit pie and meat after 2 months of storage. Such differences for fish have been found after 4 months of storage, probably because of the robust technology used to prepare fish fillets of smoked mackerel.

It has been established that the frozen food colour could successfully be characterised by the *L-value* (in accordance with the Gardner method). Favourable *L-values* for the variable regime have been detected after 4 months of storing meat, fish and fruit pie. However, poorer statistically significant average *L-values* have been established for potatoes, tomatoes, peppers, strawberries and melons within 2-4 months of storage at the variable regime.

Regarding the drip losses, statistically significant differences have been determined for tomatoes, strawberries, melons and pepper. Such unfavourable differences in quality have been established after 2 months of storage at a variable temperature of the refrigerating medium. No statistically significant differences in the drip losses have been found for potatoes, fruit (strawberry) pie, fish and meat stored in frozen state at constant and variable temperature regime. The specific texture of these products and previous culinary treatments (blanching, smoking, and backing) likely play a substantial role to ensure a much better preservation.

This study revealed that, as a rule, the food quality of frozen products subject to fluctuations of storage temperature is inferior as compared with food maintained at a constant temperature (as per the classical food refrigeration standards and good practices established). However, for many products (see Tables 1-21) this quality decay is negligible and can be offset by the obvious economic benefits, which the Night Wind concept can afford.

Table 1**Food texture during frozen storage at constant and variable temperature regimes (g/cm²)**

| № | Food | Frozen storage at constant temperature | | | | Frozen storage at variable temperature | | | |
|-----|--------------------------------|--|--------------------|---------------------------|--------------------|--|--------------------|---------------------------|--------------------|
| | | Beginning (after 3 days of storage) | | After 2 months of storage | | Beginning (after 3 days of storage) | | After 2 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 300,00 | 0,10 | 290,00 | 0,01 | 300,00 | 0,01 | 280,00 | 0,02 |
| 2. | Strawberry pie | 580,00 | 0,20 | 580,00 | 0,15 | 600,00 | 0,10 | 590,00 | 0,20 |
| 3. | Ice cream | – | – | – | – | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 330,00 | 0,20 | 300,00 | 0,25 | 295,00 | 0,35 | 300,00 | 0,18 |
| 5. | Meat (bacon) | 480,00 | 0,10 | 420,00 | 0,15 | 480,00 | 0,15 | 450,00 | 0,20 |
| 6. | Tomatoes | 95,00 | 0,25 | 40,00 | 0,10 | 95,00 | 0,20 | 45,00 | 0,15 |
| 7. | Strawberries | 150,00 | 0,01 | 90,00 | 0,15 | 140,00 | 0,02 | 55,00 | 0,20 |
| 8. | Melons | 550,00 | 0,35 | 220,00 | 0,45 | 600,00 | 0,25 | 180,00 | 0,35 |
| 9. | Peppers (Capia) | 150,00 | 0,45 | 80,00 | 0,15 | 180,00 | 0,35 | 90,00 | 0,20 |
| 10. | Peppers (Sivria) | 250,00 | 0,40 | 180,00 | 0,20 | 240,00 | 0,30 | 150,00 | 0,15 |

Food colour during frozen storage at constant and variable temperature regimes – “*L-value*”

| № | Food | Frozen storage at constant temperature | | | | Frozen storage at variable temperature | | | |
|-----|-----------------------------------|--|--------------------|---------------------------|--------------------|--|--------------------|---------------------------|--------------------|
| | | Beginning (after 3 days of storage) | | After 2 months of storage | | Beginning (after 3 days of storage) | | After 2 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 76,46 | 2,13 | 81,55 | 1,28 | 75,91 | 1,93 | 83,35 | 2,45 |
| 2. | Strawberry pie | 50,24 | 1,14 | 51,12 | 1,82 | 51,07 | 4,12 | 49,46 | 3,11 |
| 3. | Ice cream | 106,54 | 3,81 | 97,62 | 3,13 | 106,73 | 2,18 | 96,85 | 3,42 |
| 4. | Fish (smoked Mackerel fillets) | 32,55 | 3,77 | 30,21 | 2,98 | 33,11 | 2,45 | 31,25 | 1,18 |
| 5. | Meat (bacon) | 65,28 | 5,34 | 64,35 | 8,23 | 65,72 | 4,98 | 64,53 | 2,91 |
| 6. | Tomatoes | 34,37 | 1,05 | 33,21 | 1,95 | 33,14 | 1,92 | 34,05 | 1,12 |
| 7. | Strawberries | 30,15 | 1,82 | 27,51 | 1,45 | 32,81 | 2,14 | 22,10 | 2,83 |
| 8. | Melons | 58,99 | 1,97 | 58,16 | 1,33 | 58,16 | 1,13 | 62,66 | 1,97 |
| 9. | Peppers (Capia) | 39,51 | 2,13 | 38,10 | 1,96 | 39,18 | 1,18 | 37,83 | 1,15 |
| 10. | Peppers (Sivria) | 37,11 | 2,45 | 34,15 | 2,97 | 38,45 | 1,70 | 35,12 | 2,88 |

Food colour during frozen storage at constant and variable temperature regimes – “*a-value*”

| № | Food | Frozen storage at constant temperature | | | | Frozen storage at variable temperature | | | |
|-----|-----------------------------------|--|--------------------|---------------------------|--------------------|--|--------------------|---------------------------|--------------------|
| | | Beginning (after 3 days of storage) | | After 2 months of storage | | Beginning (after 3 days of storage) | | After 2 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | -1,20 | 0,34 | -1,44 | 0,28 | -1,11 | 0,43 | -3,25 | 0,78 |
| 2. | Strawberry pie | 9,50 | 2,42 | 9,07 | 2,88 | 8,78 | 2,95 | 8,58 | 3,26 |
| 3. | Ice cream | -1,80 | 0,25 | -1,74 | 0,38 | -1,95 | 0,15 | -3,91 | 2,14 |
| 4. | Fish (smoked Mackerel fillets) | 1,44 | 0,11 | 2,77 | 0,72 | 1,62 | 0,99 | 4,95 | 1,32 |
| 5. | Meat (bacon) | 8,36 | 0,27 | 8,99 | 0,78 | 8,89 | 0,28 | 10,54 | 1,94 |
| 6. | Tomatoes | 33,71 | 0,12 | 33,81 | 0,14 | 33,63 | 0,11 | 29,93 | 2,25 |
| 7. | Strawberries | 30,04 | 1,10 | 28,63 | 0,55 | 29,46 | 2,13 | 21,68 | 1,92 |
| 8. | Melons | -7,46 | 1,55 | -7,51 | 0,23 | -7,51 | 1,77 | 10,19 | 0,56 |
| 9. | Peppers (Capia) | 10,39 | 2,15 | 7,17 | 3,52 | 10,46 | 3,10 | 4,71 | 1,15 |
| 10. | Peppers (Sivria) | 7,01 | 0,59 | 6,10 | 0,92 | 7,51 | 1,05 | 7,68 | 1,09 |

Food colour during frozen storage at constant and variable temperature regimes – “*b-value*”

| № | Food | Frozen storage at constant temperature | | | | Frozen storage at variable temperature | | | |
|-----|-----------------------------------|--|--------------------|---------------------------|--------------------|--|--------------------|---------------------------|--------------------|
| | | Beginning (after 3 days of storage) | | After 2 months of storage | | Beginning (after 3 days of storage) | | After 2 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 24,69 | 1,21 | 26,83 | 1,35 | 25,51 | 0,92 | 27,14 | 1,15 |
| 2. | Strawberry pie | 17,86 | 0,58 | 17,59 | 0,66 | 17,71 | 0,42 | 16,89 | 0,93 |
| 3. | Ice cream | 9,24 | 0,21 | 9,87 | 0,17 | 9,35 | 0,31 | 18,30 | 1,92 |
| 4. | Fish (smoked Mackerel fillets) | 11,74 | 1,42 | 10,31 | 0,78 | 11,71 | 1,78 | 9,21 | 1,21 |
| 5. | Meat (bacon) | 12,39 | 1,35 | 11,98 | 1,72 | 12,26 | 1,68 | 11,45 | 2,05 |
| 6. | Tomatoes | 16,59 | 0,28 | 16,76 | 0,35 | 16,63 | 0,23 | 17,67 | 0,38 |
| 7. | Strawberries | 12,98 | 1,03 | 12,13 | 0,77 | 11,99 | 1,37 | 8,68 | 0,13 |
| 8. | Melons | 24,91 | 1,87 | 25,03 | 0,66 | 25,27 | 1,35 | 25,11 | 0,23 |
| 9. | Peppers (Capia) | 20,78 | 0,31 | 19,54 | 0,37 | 20,55 | 0,40 | 18,99 | 0,32 |
| 10. | Peppers (Sivria) | 16,37 | 0,99 | 17,19 | 0,58 | 17,33 | 1,14 | 19,52 | 0,33 |

Drip losses after thawing of frozen foods stored at constant and variable temperature regimes (ml / 100g_{product})

| № | Food | Frozen storage at constant temperature | | | | Frozen storage at variable temperature | | | |
|-----|--------------------------------|--|--------------------|---------------------------|--------------------|--|--------------------|---------------------------|--------------------|
| | | Beginning (after 3 days of storage) | | After 2 months of storage | | Beginning (after 3 days of storage) | | After 2 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 0,30 | 0,001 | 0,30 | 0,001 | 0,20 | 0,001 | 0,20 | 0,001 |
| 2. | Strawberry pie | 0,30 | 0,01 | 0,30 | 0,02 | 0,40 | 0,01 | 0,40 | 0,01 |
| 3. | Ice cream | – | – | – | – | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 1,00 | 0,001 | 1,00 | 0,001 | 0,90 | 0,001 | 0,90 | 0,001 |
| 5. | Meat (bacon) | 6,90 | 0,01 | 7,60 | 0,01 | 6,80 | 0,01 | 7,5 | 0,01 |
| 6. | Tomatoes | 40,80 | 0,03 | 50,80 | 0,01 | 40,90 | 0,02 | 52,30 | 0,08 |
| 7. | Strawberries | 30,80 | 0,02 | 34,50 | 0,02 | 35,00 | 0,01 | 35,70 | 0,01 |
| 8. | Melons | 40,20 | 0,03 | 45,00 | 0,02 | 41,80 | 0,05 | 49,00 | 0,15 |
| 9. | Peppers (Capia) | 28,30 | 0,01 | 29,90 | 0,01 | 28,00 | 0,03 | 28,70 | 0,09 |
| 10. | Peppers (Sivria) | 23,70 | 0,01 | 26,80 | 0,03 | 24,50 | 0,01 | 27,70 | 0,15 |

Food texture during frozen storage at constant and variable temperature regimes (g/cm²)

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 4 months of storage | | After 4 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 520,00 | 0,95 | 610,00 | 0,33 |
| 2. | Strawberry pie | 620,00 | 0,48 | 600,00 | 0,45 |
| 3. | Ice cream | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 390,00 | 0,77 | 450,00 | 0,66 |
| 5. | Meat (bacon) | 510,00 | 0,48 | 620,00 | 0,84 |
| 6. | Tomatoes | 50,00 | 0,11 | 40,00 | 0,12 |
| 7. | Strawberries | 210,00 | 0,18 | 150,00 | 0,11 |
| 8. | Melons | 100,00 | 0,28 | 70,00 | 0,10 |
| 9. | Peppers (Capia) | 290,00 | 0,13 | 320,00 | 0,56 |
| 10. | Peppers (Sivria) | 310,00 | 0,33 | 350,00 | 0,25 |

Food colour during frozen storage at constant and variable temperature regimes – “*L-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 4 months of storage | | After 4 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 81,72 | 1,21 | 82,61 | 1,69 |
| 2. | Strawberry pie | 46,47 | 0,94 | 47,20 | 1,88 |
| 3. | Ice cream | 105,66 | 2,14 | 106,07 | 1,67 |
| 4. | Fish (smoked Mackerel fillets) | 38,39 | 4,21 | 35,23 | 7,89 |
| 5. | Meat (bacon) | 49,66 | 13,23 | 52,71 | 11,19 |
| 6. | Tomatoes | 29,01 | 3,96 | 31,04 | 2,98 |
| 7. | Strawberries | 26,63 | 0,96 | 22,03 | 0,84 |
| 8. | Melons | 45,40 | 0,96 | 44,10 | 0,75 |
| 9. | Peppers (Capia) | 38,72 | 10,01 | 36,30 | 8,92 |
| 10. | Peppers (Sivria) | 38,42 | 7,55 | 37,32 | 6,97 |

Food colour during frozen storage at constant and variable temperature regimes – “*a-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|--------------------------------|--|--------------------|--|--------------------|
| | | After 4 months of storage | | After 4 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | -1,21 | 0,96 | -1,69 | 0,56 |
| 2. | Strawberry pie | 19,87 | 0,96 | 16,55 | 0,87 |
| 3. | Ice cream | -1,74 | 0,24 | 2,24 | 0,96 |
| 4. | Fish (smoked Mackerel fillets) | 8,71 | 0,92 | 4,29 | 0,38 |
| 5. | Meat (bacon) | 5,93 | 0,67 | 13,26 | 0,67 |
| 6. | Tomatoes | 31,01 | 3,11 | 23,73 | 0,65 |
| 7. | Strawberries | 27,66 | 0,90 | 20,38 | 0,91 |
| 8. | Melons | -6,49 | 1,05 | 0,75 | 4,31 |
| 9. | Peppers (Capia) | 6,83 | 2,41 | 5,05 | 1,55 |
| 10. | Peppers (Sivria) | 7,63 | 0,95 | 6,97 | 0,66 |

Food colour during frozen storage at constant and variable temperature regimes – “*b-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 4 months of storage | | After 4 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 24,23 | 0,61 | 26,67 | 0,67 |
| 2. | Strawberry pie | 19,53 | 0,67 | 19,50 | 0,23 |
| 3. | Ice cream | 11,62 | 0,58 | 9,64 | 0,68 |
| 4. | Fish (smoked Mackerel fillets) | 10,14 | 1,12 | 7,89 | 0,98 |
| 5. | Meat (bacon) | 12,39 | 0,67 | 19,92 | 3,85 |
| 6. | Tomatoes | 14,83 | 0,65 | 13,51 | 0,97 |
| 7. | Strawberries | 10,69 | 1,21 | 7,67 | 0,67 |
| 8. | Melons | 15,71 | 0,67 | 15,59 | 0,32 |
| 9. | Peppers (Capia) | 17,55 | 0,61 | 15,01 | 0,61 |
| 10. | Peppers (Sivria) | 19,25 | 0,98 | 18,95 | 0,1 |

Drip losses after thawing of frozen foods stored at constant and variable temperature regimes (ml / 100g_{product})

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|--------------------------------|--|--------------------|--|--------------------|
| | | After 4 months of storage | | After 4 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 0,00 | 0,00 | 0,00 | 0,00 |
| 2. | Strawberry pie | 0,00 | 0,00 | 0,00 | 0,00 |
| 3. | Ice cream | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 0,00 | 0,00 | 0,00 | 0,00 |
| 5. | Meat (bacon) | 0,00 | 0,00 | 0,00 | 0,00 |
| 6. | Tomatoes | 51,00 | 0,12 | 53,00 | 0,18 |
| 7. | Strawberries | 36,00 | 0,11 | 38,00 | 0,12 |
| 8. | Melons | 48,00 | 0,13 | 51,00 | 0,12 |
| 9. | Peppers (Capia) | 31,00 | 0,12 | 29,00 | 0,11 |
| 10. | Peppers (Sivria) | 28,00 | 0,11 | 28,00 | 0,12 |

Food texture during frozen storage at constant and variable temperature regimes (g/cm²)

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 6 months of storage | | After 6 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 520,00 | 0,90 | 615,00 | 0,30 |
| 2. | Strawberry pie | 625,00 | 0,40 | 600,00 | 0,35 |
| 3. | Ice cream | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 400,00 | 0,85 | 450,00 | 0,75 |
| 5. | Meat (bacon) | 510,00 | 0,45 | 625,00 | 0,80 |
| 6. | Tomatoes | 50,00 | 0,10 | 40,00 | 0,10 |
| 7. | Strawberries | 205,00 | 0,20 | 150,00 | 0,10 |
| 8. | Melons | 95,00 | 0,30 | 70,00 | 0,10 |
| 9. | Peppers (Capia) | 290,00 | 0,10 | 315,00 | 0,45 |
| 10. | Peppers (Sivria) | 310,00 | 0,30 | 350,00 | 0,20 |

Food colour during frozen storage at constant and variable temperature regimes – “*L-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 6 months of storage | | After 6 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 82,02 | 0,91 | 82,13 | 0,95 |
| 2. | Strawberry pie | 46,52 | 0,90 | 47,11 | 0,93 |
| 3. | Ice cream | 105,00 | 1,14 | 106,00 | 0,98 |
| 4. | Fish (smoked Mackerel fillets) | 38,02 | 2,12 | 36,77 | 4,35 |
| 5. | Meat (bacon) | 50,09 | 5,18 | 52,80 | 5,42 |
| 6. | Tomatoes | 29,00 | 1,72 | 31,00 | 0,91 |
| 7. | Strawberries | 26,75 | 0,12 | 22,18 | 0,75 |
| 8. | Melons | 45,00 | 0,85 | 44,01 | 0,75 |
| 9. | Peppers (Capia) | 39,11 | 5,13 | 36,12 | 4,15 |
| 10. | Peppers (Sivria) | 38,50 | 2,48 | 37,10 | 2,38 |

Food colour during frozen storage at constant and variable temperature regimes – “*a-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 6 months of storage | | After 6 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | -1,21 | 0,95 | -1,70 | 0,45 |
| 2. | Strawberry pie | 19,22 | 0,95 | 16,75 | 0,87 |
| 3. | Ice cream | -1,75 | 0,12 | 2,20 | 0,93 |
| 4. | Fish (smoked Mackerel fillets) | 8,70 | 0,75 | 4,35 | 0,11 |
| 5. | Meat (bacon) | 6,02 | 0,25 | 13,42 | 0,15 |
| 6. | Tomatoes | 31,00 | 1,15 | 23,70 | 0,19 |
| 7. | Strawberries | 27,92 | 0,78 | 20,45 | 0,92 |
| 8. | Melons | -6,50 | 0,91 | 0,80 | 0,35 |
| 9. | Peppers (Capia) | 6,80 | 1,35 | 5,00 | 0,98 |
| 10. | Peppers (Sivria) | 7,80 | 0,99 | 6,99 | 0,35 |

Food colour during frozen storage at constant and variable temperature regimes – “*b-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 6 months of storage | | After 6 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 24,51 | 0,42 | 26,53 | 0,51 |
| 2. | Strawberry pie | 19,50 | 0,38 | 19,58 | 0,12 |
| 3. | Ice cream | 11,93 | 0,51 | 9,71 | 0,63 |
| 4. | Fish (smoked Mackerel fillets) | 10,01 | 0,98 | 8,04 | 0,72 |
| 5. | Meat (bacon) | 12,35 | 0,48 | 20,05 | 1,34 |
| 6. | Tomatoes | 14,98 | 0,49 | 13,71 | 0,97 |
| 7. | Strawberries | 10,50 | 0,98 | 7,62 | 0,48 |
| 8. | Melons | 15,85 | 0,71 | 15,48 | 0,21 |
| 9. | Peppers (Capia) | 17,58 | 0,41 | 15,21 | 0,35 |
| 10. | Peppers (Sivria) | 19,30 | 0,99 | 20,04 | 0,10 |

Drip losses after thawing of frozen foods stored at constant and variable temperature regimes (ml / 100g_{product})

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|--------------------------------|--|--------------------|--|--------------------|
| | | After 6 months of storage | | After 6 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 0,00 | 0,00 | 0,00 | 0,00 |
| 2. | Strawberry pie | 0,00 | 0,00 | 0,00 | 0,00 |
| 3. | Ice cream | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 0,00 | 0,00 | 0,00 | 0,00 |
| 5. | Meat (bacon) | 2,50 | 0,10 | 2,80 | 0,09 |
| 6. | Tomatoes | 2,60 | 0,08 | 2,50 | 0,09 |
| 7. | Strawberries | 1,80 | 0,09 | 1,50 | 0,08 |
| 8. | Melons | 2,30 | 0,11 | 2,10 | 0,07 |
| 9. | Peppers (Capia) | 1,50 | 0,07 | 2,00 | 0,09 |
| 10. | Peppers (Sivria) | 2,00 | 0,10 | 1,90 | 0,09 |

Food texture during frozen storage at constant and variable temperature regimes (g/cm²)

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 8 months of storage | | After 8 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 520,00 | 0,58 | 540,00 | 0,30 |
| 2. | Strawberry pie | 615,00 | 0,52 | 550,00 | 0,30 |
| 3. | Ice cream | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 390,00 | 0,55 | 425,00 | 0,55 |
| 5. | Meat (bacon) | 490,00 | 0,50 | 450,00 | 0,50 |
| 6. | Tomatoes | 50,00 | 0,10 | 30,00 | 0,10 |
| 7. | Strawberries | 150,00 | 0,10 | 100,00 | 0,08 |
| 8. | Melons | 55,00 | 0,10 | 50,00 | 0,08 |
| 9. | Peppers (Capia) | 230,00 | 0,10 | 210,00 | 0,10 |
| 10. | Peppers (Sivria) | 250,00 | 0,12 | 200,00 | 0,10 |

Food colour during frozen storage at constant and variable temperature regimes – “*L-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 8 months of storage | | After 8 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 83,15 | 0,55 | 82,00 | 0,55 |
| 2. | Strawberry pie | 50,18 | 0,50 | 51,35 | 0,55 |
| 3. | Ice cream | 105,00 | 0,55 | 105,00 | 0,55 |
| 4. | Fish (smoked Mackerel fillets) | 34,10 | 0,82 | 30,81 | 0,12 |
| 5. | Meat (bacon) | 53,15 | 1,13 | 53,88 | 0,15 |
| 6. | Tomatoes | 18,45 | 0,88 | 16,35 | 0,10 |
| 7. | Strawberries | 21,39 | 0,10 | 20,10 | 0,50 |
| 8. | Melons | 28,17 | 0,55 | 23,55 | 0,50 |
| 9. | Peppers (Capia) | 28,10 | 1,32 | 22,77 | 0,95 |
| 10. | Peppers (Sivria) | 29,88 | 0,96 | 23,46 | 1,05 |

Food colour during frozen storage at constant and variable temperature regimes – “*a-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 8 months of storage | | After 8 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 1,20 | 0,07 | -1,12 | 0,95 |
| 2. | Strawberry pie | 19,10 | 0,05 | 15,87 | 1,35 |
| 3. | Ice cream | -1,70 | 0,05 | -1,70 | 0,82 |
| 4. | Fish (smoked Mackerel fillets) | 7,93 | 0,10 | 3,55 | 0,54 |
| 5. | Meat (bacon) | 5,85 | 0,03 | 6,12 | 3,58 |
| 6. | Tomatoes | 35,12 | 0,48 | 34,85 | 4,12 |
| 7. | Strawberries | 30,82 | 0,35 | 33,59 | 5,08 |
| 8. | Melons | -4,51 | 0,10 | -5,33 | 4,36 |
| 9. | Peppers (Capia) | 8,29 | 1,05 | 7,78 | 1,28 |
| 10. | Peppers (Sivria) | 8,96 | 0,90 | 7,75 | 0,36 |

Food colour during frozen storage at constant and variable temperature regimes – “*b-value*”

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|-----------------------------------|--|--------------------|--|--------------------|
| | | After 8 months of storage | | After 8 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 26,85 | 0,10 | 27,15 | 0,10 |
| 2. | Strawberry pie | 20,38 | 0,10 | 22,44 | 0,10 |
| 3. | Ice cream | 11,50 | 0,10 | 10,99 | 0,12 |
| 4. | Fish (smoked Mackerel fillets) | 6,75 | 0,18 | 5,84 | 0,10 |
| 5. | Meat (bacon) | 13,41 | 0,10 | 22,36 | 0,35 |
| 6. | Tomatoes | 7,35 | 0,10 | 6,88 | 0,28 |
| 7. | Strawberries | 5,72 | 0,12 | 4,21 | 0,10 |
| 8. | Melons | 6,41 | 0,12 | 5,15 | 0,10 |
| 9. | Peppers (Capia) | 6,89 | 0,10 | 5,25 | 0,10 |
| 10. | Peppers (Sivria) | 7,14 | 0,23 | 6,18 | 0,10 |

Drip losses after thawing of frozen foods stored at constant and variable temperature regimes (ml / 100g_{product})

| № | Food | Frozen storage at constant temperature | | Frozen storage at variable temperature | |
|-----|--------------------------------|--|--------------------|--|--------------------|
| | | After 8 months of storage | | After 8 months of storage | |
| | | Average | Standard deviation | Average | Standard deviation |
| 1. | French fries (blanched) | 0,00 | 0,00 | 0,00 | 0,00 |
| 2. | Strawberry pie | 0,00 | 0,00 | 0,00 | 0,00 |
| 3. | Ice cream | – | – | – | – |
| 4. | Fish (smoked Mackerel fillets) | 0,00 | 0,00 | 0,00 | 0,00 |
| 5. | Meat (bacon) | 0,00 | 0,00 | 0,00 | 0,00 |
| 6. | Tomatoes | 1,50 | 0,01 | 2,00 | 0,01 |
| 7. | Strawberries | 1,10 | 0,01 | 2,00 | 0,01 |
| 8. | Melons | 1,50 | 0,01 | 2,00 | 0,01 |
| 9. | Peppers (Capia) | 1,00 | 0,01 | 2,00 | 0,01 |
| 10. | Peppers (Sivria) | 1,00 | 0,01 | 2,00 | 0,01 |

**Average consumer preference of sensory attributes for the products A
(maintained frozen at variable storage temperatures with freeze-thaw cycles)
as compared with the products B (stored at a constant temperature),
estimated after 3 days, and 4, 6 and 8 months of storage
by the method of Scheffe ***

| Samples | Appearance | Colour | Flavour | Consistency |
|--|------------|--------|---------|-------------|
| Fish (smoked Mackerel) – 3 days | -0.58 | -0.72 | -0.34 | -0.75 |
| Fish (smoked Mackerel) – 2 months | -0.62 | -0.87 | -0.43 | -1.12 |
| Fish (smoked Mackerel) – 4 months | -1.12 | -1.00 | -1.50 | -1.37 |
| Fish (smoked Mackerel) – 6 months | -0.37 | -0.62 | -0.75 | -0.87 |
| Fish (smoked Mackerel) – 8 months | -0.37 | -0.75 | -1.12 | -1.37 |
| Meat (bacon) – 3 days | | | | |
| Meat (bacon) – 2 months | -0.48 | -0.62 | -0.30 | -0.62 |
| Meat (bacon) – 4 months | -0.54 | -1.75 | -0.37 | -2.12 |
| Meat (bacon) – 6 months | -2.12 | -1.12 | -0.87 | -0.87 |
| Meat (bacon) – 8 months | -1.12 | -1.25 | -0.87 | -1.12 |
| Ice cream – 3 days | | | | |
| Ice cream – 2 months | -0.5 | -0.5 | -1.12 | -0.5 |
| Ice cream – 4 months | -0.30 | -0.10 | -0.75 | -0.58 |
| Ice cream – 6 months | -0.37 | -0.12 | -0.62 | -0.62 |
| Ice cream – 8 months | -0.62 | -0.75 | -0.62 | -2.00 |
| Melons – 3 days | | | | |
| Melons – 2 months | -0.31 | -0.25 | -0.75 | -0.75 |
| Melons – 4 months | -0.31 | -0.25 | -0.75 | -0.75 |
| Melons – 6 months | -0.62 | -0.50 | -0.63 | -0.12 |
| Melons – 8 months | -0.75 | -1.00 | -0.50 | -0.06 |
| Tomatoes – 3 days | | | | |
| Tomatoes – 2 months | -1.12 | -1.25 | -0.75 | -0.75 |
| Tomatoes – 4 months | -0.87 | -0.87 | -1.25 | -0.87 |
| Tomatoes – 6 months | -0.87 | -0.87 | -1.25 | -0.87 |
| Tomatoes – 8 months | -0.62 | -0.5 | -0.75 | -0.37 |
| Peppers (Sivria) – 3 days | | | | |
| Peppers (Sivria) – 2 months | -0.54 | -0.62 | -0.50 | -0.25 |
| Peppers (Sivria) – 4 months | -0.87 | -1.12 | -0.62 | -0.75 |
| Peppers (Sivria) – 6 months | -0.75 | -0.75 | -0.75 | -0.62 |
| Peppers (Sivria) – 8 months | -1.00 | -0.75 | -0.87 | -0.87 |
| Peppers (Sivria) – 3 days | | | | |
| Peppers (Sivria) – 2 months | -0.54 | -0.75 | -0.38 | -0.58 |
| Peppers (Sivria) – 4 months | -1.00 | -1.37 | -0.62 | -0.62 |
| Peppers (Sivria) – 6 months | -0.75 | -0.50 | -0.75 | -1.12 |
| Peppers (Sivria) – 8 months | -1.12 | -0.87 | -0.50 | -0.87 |

Scores for detecting sensory differences by using the Scheffe's method:

3 (A is enormously better than B); 2 (A is much better than B); 1 (A is better than B);

0 (no difference); -1 (B is better than A); -2 (B is much better than A);

-3 (B is enormously better than A).

Table 21 (continued)

Average consumer preference of sensory attributes for the products A (maintained frozen at variable storage temperatures with freeze-thaw cycles) as compared with the products B (stored at a constant temperature), estimated after 3 days, and 2, 4, 6 and 8 months of storage by the method of Scheffe *

| Samples | Appearance | Colour | Flavour | Consistency |
|---|-------------------|---------------|----------------|--------------------|
| Peppers (Capia)– 3 days | -0.75 | -0.58 | -0.62 | -0.25 |
| Peppers (Capia) – 2 months | -0.87 | -1.00 | -0.75 | -0.37 |
| Peppers (Capia) – 4 months | -1.00 | -1.37 | -1.12 | -1.25 |
| Peppers (Capia) – 6 months | -0.72 | -1.00 | -1.00 | -0.75 |
| Peppers (Capia) – 8 months | -0.87 | -1.12 | -0.38 | -0.62 |
| Strawberries – 3 days | | | | |
| Strawberries – 3 days | -0.54 | -0.28 | -0.25 | -0.28 |
| Strawberries – 2 months | -1.00 | -1.00 | -0.75 | -0.75 |
| Strawberries – 4 months | -1.50 | -1.12 | -1.00 | -1.25 |
| Strawberries – 6 months | -0.50 | -0.62 | -0.87 | -0.62 |
| Strawberries – 8 months | -0.37 | -0.5 | -0.5 | -0.12 |
| French fries (blanched) – 3 days | | | | |
| French fries (blanched) – 3 days | -0.10 | -0.12 | -0.35 | -0.54 |
| French fries (blanched) – 2 months | -0.12 | -0.25 | -0.75 | -1.37 |
| French fries (blanched) – 4 months | -0.62 | -0.50 | -1.00 | -0.87 |
| French fries (blanched) – 6 months | -0.37 | -0.62 | -0.50 | -0.50 |
| French fries (blanched) – 8 months | -0.12 | -0.37 | -0.37 | -0.32 |
| Fruit pie – 3 days | | | | |
| Fruit pie – 3 days | -0.16 | -0.10 | -0.62 | -0.25 |
| Fruit pie – 2 months | -0.75 | -0.12 | -0.75 | -0.50 |
| Fruit pie – 4 months | -0.75 | -0.37 | -0.62 | -1.00 |
| Fruit pie – 6 months | -0.50 | -0.50 | -1.00 | -0.50 |
| Fruit pie – 8 months | -0.62 | -0.12 | -0.5 | -0.37 |

Scores for detecting sensory differences by using the Scheffe's method:
3 (A is enormously better than B); 2 (A is much better than B); 1 (A is better than B);
0 (no difference); -1 (B is better than A); -2 (B is much better than A);
-3 (B is enormously better than A).