Ingredient interactions with EXBERRY® in low pH non-alcoholic beverages

NAB Category Team

GROWING COLORS

EXBERRY®

1

Possible interactions of EXBERRY® with beverage ingredients

GROWING COLORS EXBERRY®

Possible interactions of EXBERRY® products with beverage ingredients and important parameters of the beverage base

1. pH value
2. Ascorbic acid
3. Sulphur dioxide
4. Quinine
5. Sweeteners & Acidifiers
6. Flavors / Essential oils
7. Other ingredients

Influence of pH value (1)

EXBERRY® Shade Vivid Red

Recipe A	Recipe B
Demineralized water + 0.05 % EXBERRY® Shade Vivid Red	Mineral water + 0.05 % EXBERRY® Shade Vivid Red

pH 4.7

pH 6.7

- Most EXBERRY® products are sour due to the acidity of the raw materials or due to the addition of citric acid.
- When EXBERRY® is added to water the pH value drops.
- Depending on the water quality, the final pH value can vary.
- Mineral waters may have an acid buffering effect:
  - Ability to resist changes in pH value with respect to the addition of acid
  - “alkalinity” or “acid neutralizing capacity”
- Demineralized water has nearly no buffer capacity. Therefore, the pH value will decrease rapidly after EXBERRY® addition.

Influence of pH value (2)

EXBERRY® Shade Vivid Red

Recipe A

Demineralized water
+ 0.05 % EXBERRY® Shade Vivid Red
+ 0.07 % Citric acid

pH 4.7 pH 3.0

Recipe B

Mineral water
+ 0.05 % EXBERRY® Shade Vivid Red
+ 0.07 % Citric acid

pH 6.7 pH 5.0

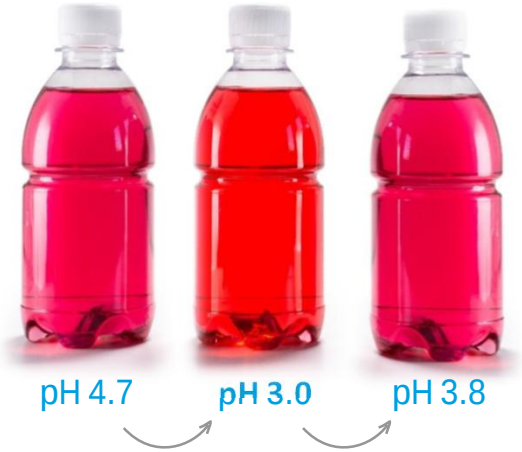
- With addition of citric acid or another food acid the pH value decreases.
- Changing the pH value can significantly change the color shade of red, pink and purple EXBERRY®.

Influence of pH value (3)

EXBERRY® Shade Vivid Red

Recipe A

Demineralized water
+ 0.05 % EXBERRY® Shade Vivid Red
+ 0.07 % Citric acid
+ 0.04 % Trisodium citrate



Recipe B

Mineral water
+ 0.05 % EXBERRY® Shade Vivid Red
+ 0.07 % Citric acid
+ 0.10 % Citric acid

- The final pH value of a beverage depends not only on the amount and type of acids but on the overall matrix.
- In practice, the specified range for the acid content [g/L or g/kg] is much narrower than the specified range for the pH value.
- However, for the color shade of EXBERRY® the pH value is more important than the acid content!

Influence of pH value: Red / pink / purple EXBERRY® (4)

- Appearance of RED, PINK & PURPLE EXBERRY® at different pH values

EXBERRY® products made from red fruits and vegetables that contain anthocyanins are pH dependent.

Influence of pH value: Red / pink / purple EXBERRY® (5)

- Anthocyanin-based EXBERRY® products at pH levels between 2.7 and 3.9

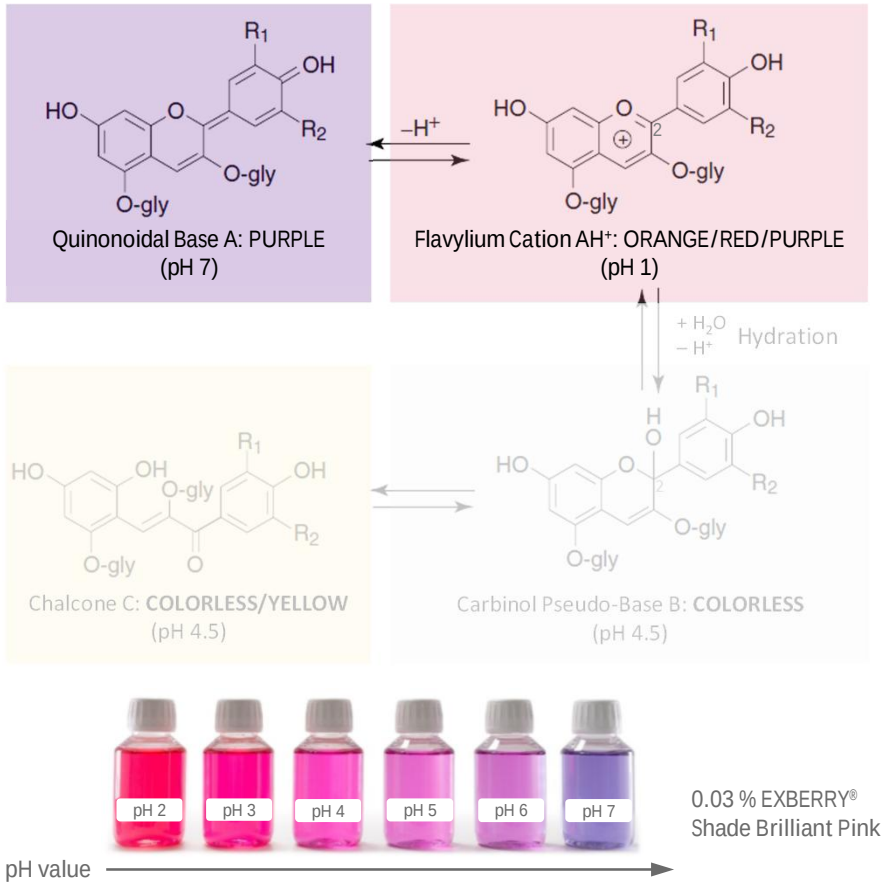
0.03 % EXBERRY® Shade Vivid Red

0.03 % EXBERRY® Shade Brilliant Pink

- In practice, the specified range for the total acid content [g/L or g/kg] is much narrower than the specified range for the pH value
- However, for the color shade of EXBERRY® the pH value is more important than the acid content!

Influence of pH value: Red / pink / purple EXBERRY® (6)

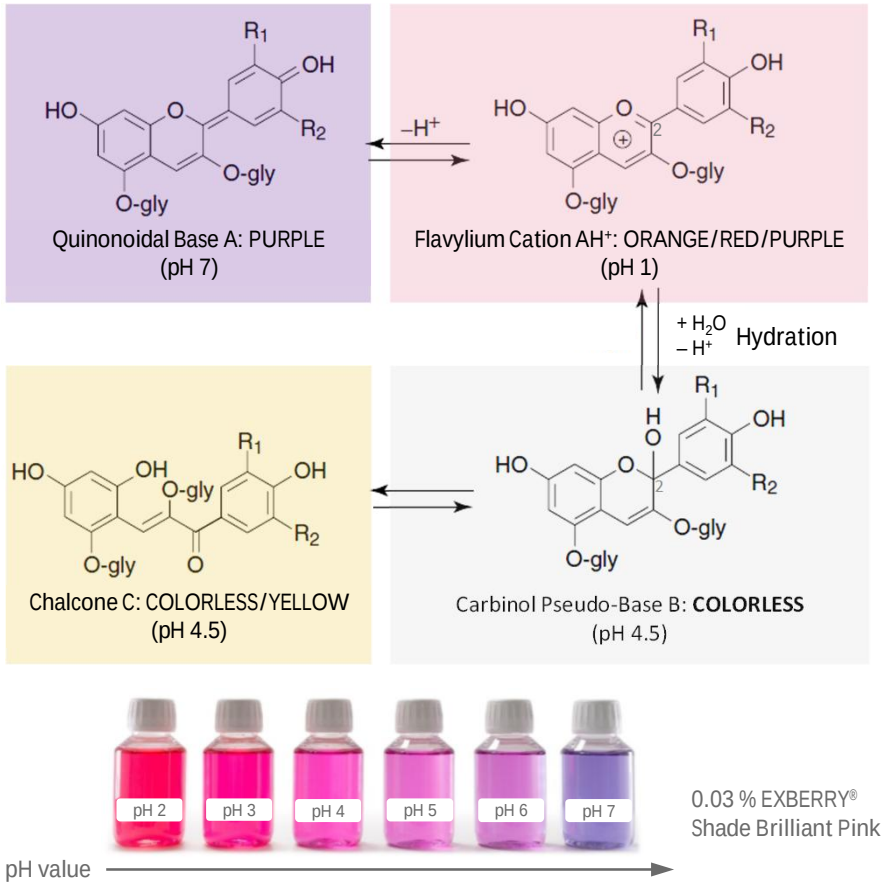
- Transformation of anthocyanins at different pH values



- The color shade of anthocyanins depends on the pH value of the application.
- 4 molecular anthocyanin configurations exist in equilibrium:
  - Flavylium cation AH+: RED
  - Quinonoidal Base A: PURPLE
  - Carbinol Pseudo-Base B: COLORLESS
  - Chalcone C: COLORLESS-YELLOW
- All forms are present at the same time. The relative amount of each form at equilibrium varies with pH value and anthocyanin structure.
- At acidic pH value (< 2) the red flavylium cation is dominant.
- At increasing pH conditions (3-6), colorless carbinol pseudo-base and chalcone structures are formed.
- At neutral pH value (7) the blue quinonoidal base is dominant.
- At pH 4–6, an anthocyanin solution has very little hue due to the small amount of flavylium cation and quinonoidal base!

Influence of pH value: Red / pink / purple EXBERRY® (6)

- Transformation of anthocyanins at different pH values



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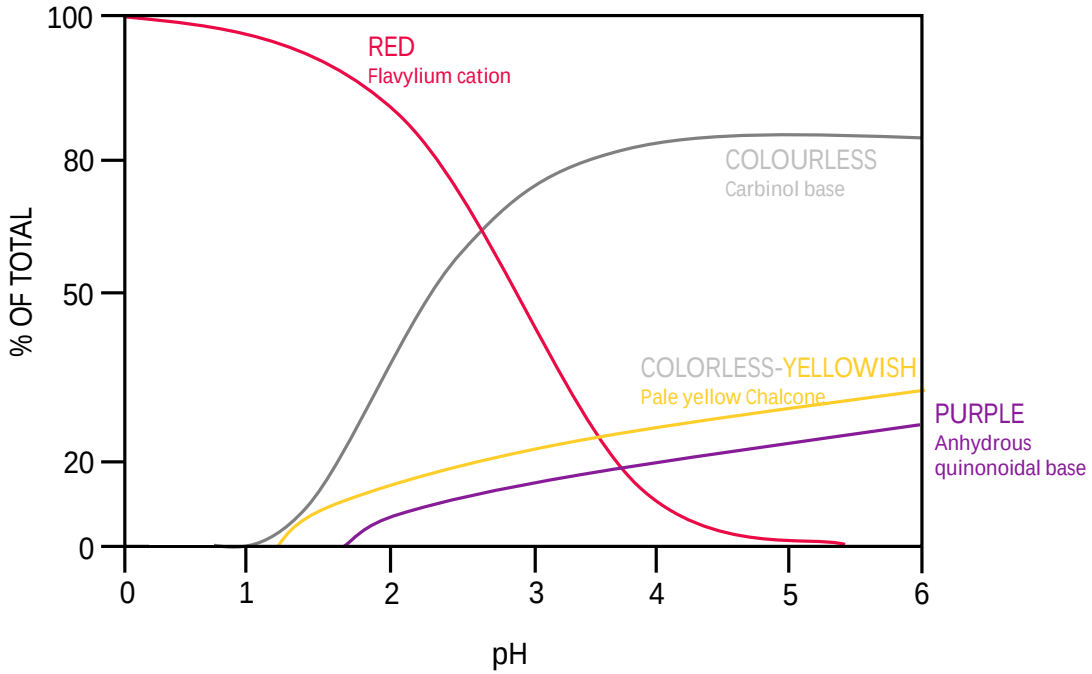
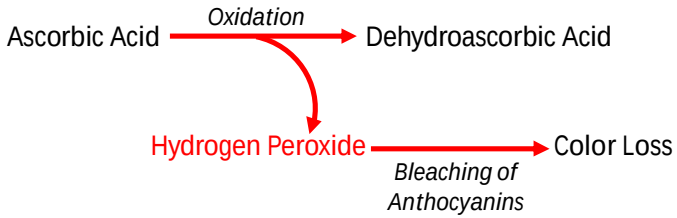
Influence of pH value: Red / pink / purple EXBERRY® (8)



Influence of ascorbic acid

Product parameters: 8° Brix
pH 3.0
Cold preserved

- Ascorbic acid oxidation bi-products can irreversibly bleach anthocyanin-based EXBERRY® products



0.03 % EXBERRY®
Shade Vivid Red

- Ascorbic acid protects carotenoid-based EXBERRY® products from oxidation

0.13 % EXBERRY®
Shade Mandarin

Influence of sulphur dioxide

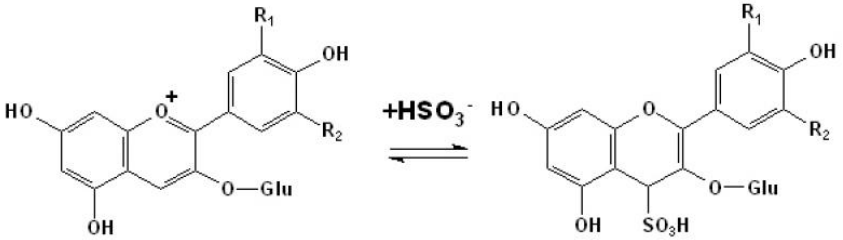
EXBERRY® Shade Vivid Red

Recipe A

Demineralized water
+ 0.05 % EXBERRY® Shade Vivid Red
+ 0.07 % Citric acid
+ 0.04 % Trisodium citrate
+ 0.02 % Sodium metabisulfite

pH 3.8 pH 3.8

- Sulphur dioxide forms colorless complexes with anthocyanin-based EXBERRY® products

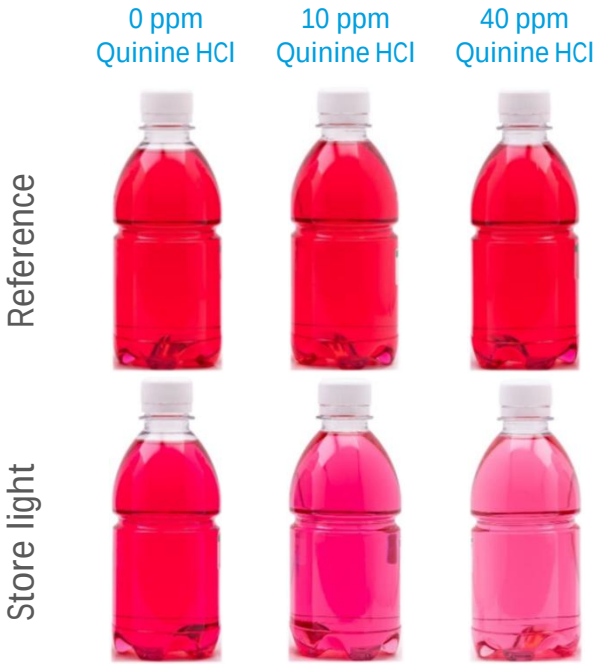


Flavylium cation
RED

Anthocyanin-bisulfite complex
(flavene sulfonate)
COLORLESS

Influence of quinine

- The presence of quinine can cause color loss of anthocyanin-based EXBERRY® products
- The degradation reaction is light driven and substantial in clear bottles when exposed to store light or UV light
- This reaction is not reversible!

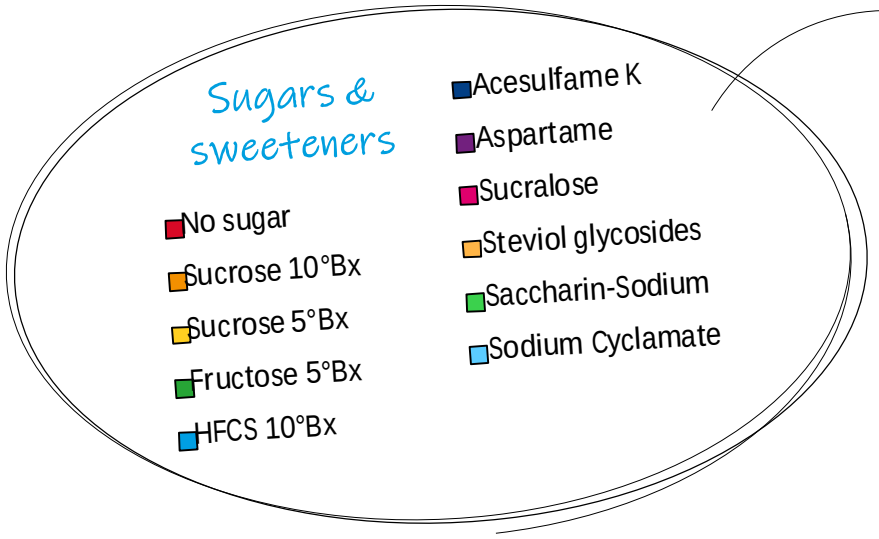


0.07 % EXBERRY®
Shade Brilliant Pink

Influence of the sweetening system

Complete study

- There are no significant differences in color retention whether a beverage is unsweetened or contains sugars or high intense sweeteners
- The sweetening system in soft drinks can be easily changed without consideration of significant color fading as long as the pH value remains the same

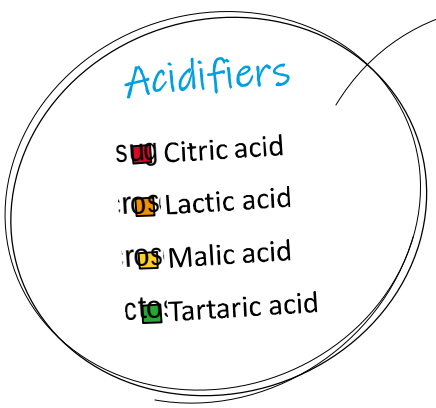


Same color stability at same pH value!

Influence of acidifier type

Complete study

- There are no significant differences in color retention whether citric acid or any other fruit acid is used
- The acidifier in soft drinks can be easily changed without consideration of significant color fading as long as the pH value remains the same



Same color stability at same pH value!

Current studies running on influence of acidifier dosage at same pH value!

Influence of vitamins and minerals

- Internal project with results of vitamin/mineral interactions on a rainbow EXBERRY® performance with photos, color retention graphs and performance grading tables

Vitamins & minerals

- No Vitamin
- Vitamin B1 (Thiamin hydrochloride)
- Vitamin B3 – Niacin (Nicotinamide)
- Vitamin B5 (Calcium D-pantothenate)
- Vitamin B6 (Pyridoxine HCl)
- Vitamin B12 (Cyanocobalamin)
- Vitamin C* (Ascorbic acid) - 7.5% RI
- Vitamin C* (Ascorbic acid) - 15% RI
- Vitamin D (Cholecalciferol)
- Folic acid
- Biotin
- Zinc Gluconate

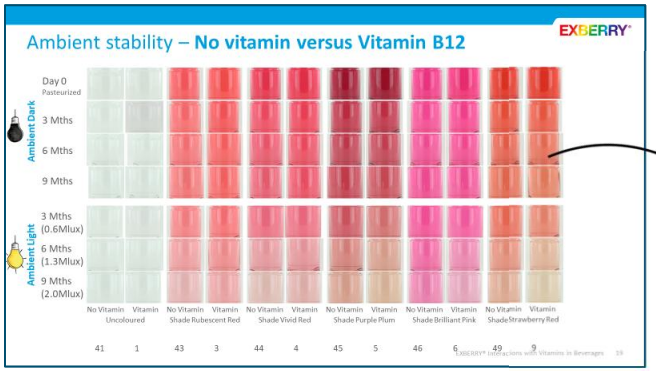
Dosed at 100% RI, except Vitamin C

Anthocyanin-based EXBERRY® products:

- **Negative effect: Vitamin C (ascorbic acid)**
- **No effect: Vitamins B1, B3, D, Biotin**
- **(Slight) positive effect: Vitamins B5, B6, B12, Folic acid, Zinc**

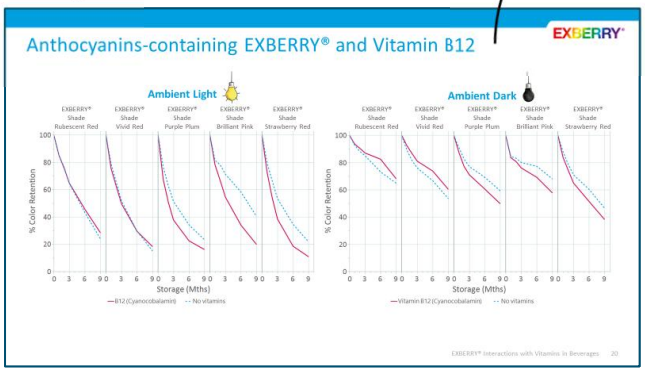
Study to evaluate vitamin/mineral interactions in NAB

Anthocyanin based red, pink and purple EXBERRY® with Vitamin B12

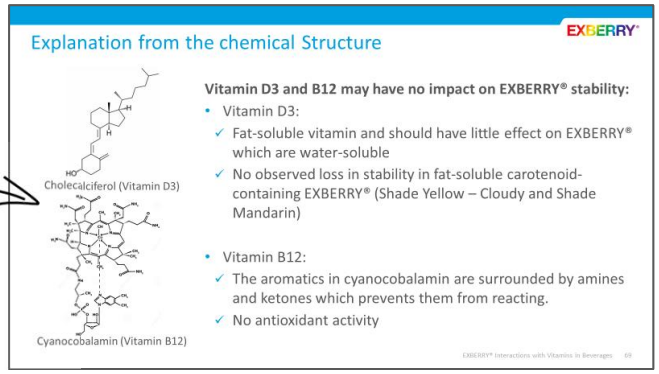


Ambient light and dark photo results

Comparison is always against base with no vit/minerals



Ambient light and dark analytical as percentage color retention against no vit/minerals

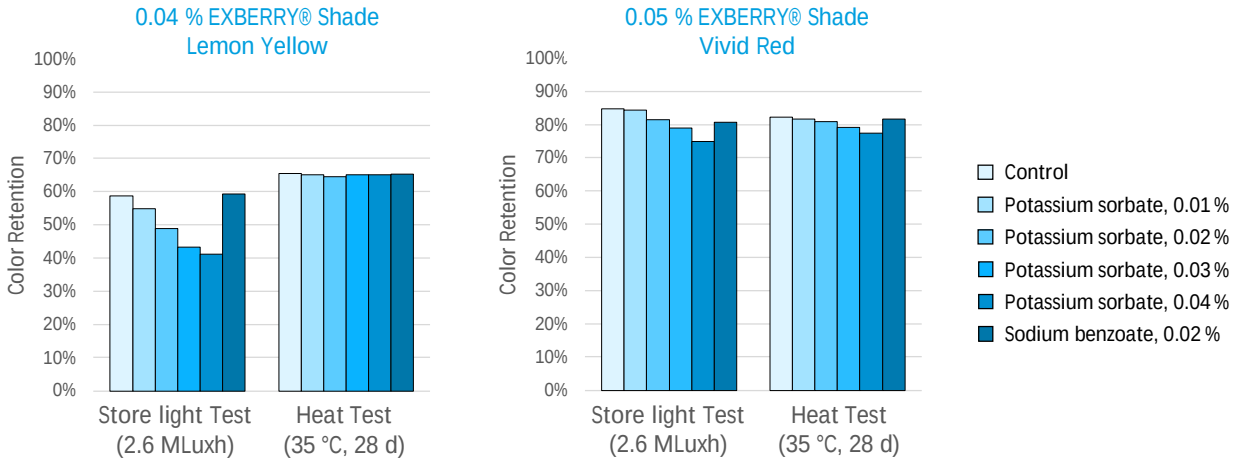


Explanation on the chemical structures and natural pigment interactions

Influence of preservatives

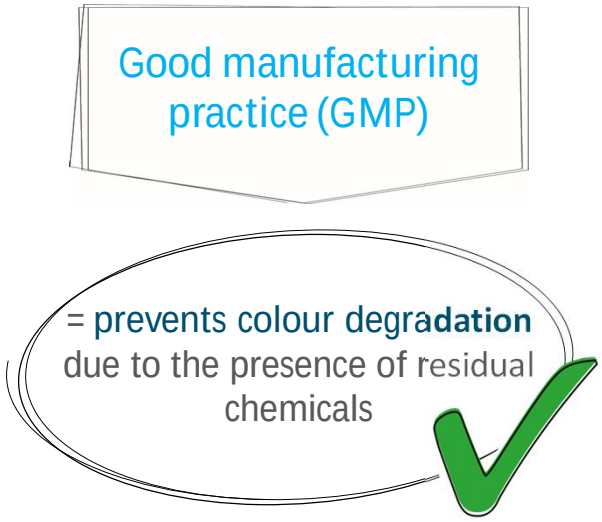
* Maximum dosages in soft drinks according to Regulation (EC) No 1333/2008 on food additives

- Potassium sorbate
  - Negative impact on the color stability of EXBERRY® Shade Lemon Yellow, but only under light stress
  - Slight negative impact on the color stability of anthocyanin-based EXBERRY® products under light and heat stress
    - Color retention for these EXBERRY® products decreases with increasing dosage of sorbate (100-400* ppm)
- Sodium benzoate
  - No significant impact on EXBERRY® performance (180* ppm)



Influence of cleaning agents

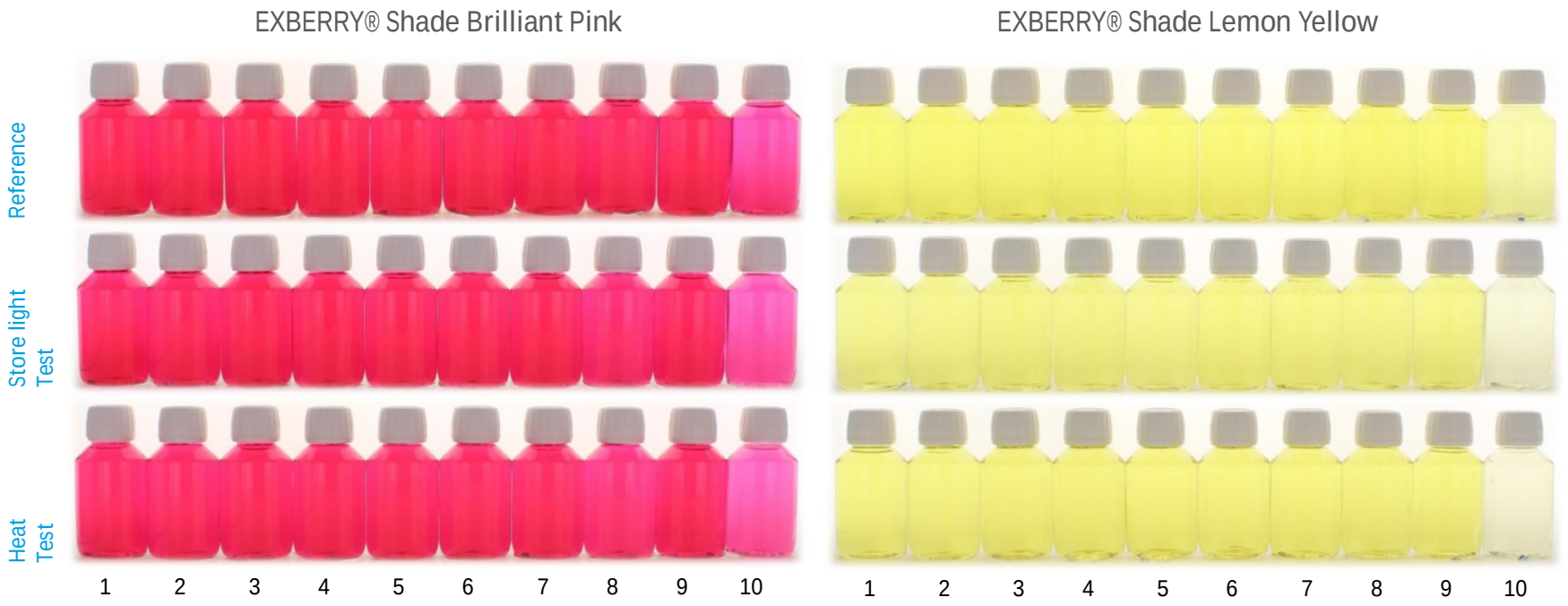
- Residual acidic or alkaline cleaning agents in pipes or tanks
- Residual sterilization fluids in filling process
  - ➢ Influence colour shade and stability of EXBERRY®



Study planned to evaluate impact of cleaning agents

Influence of flavors and essential oils (1)

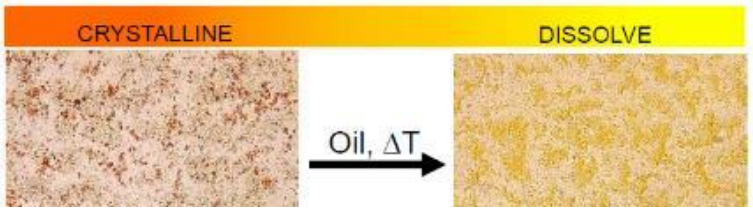
- Some flavoring's component can impact EXBERRY® stability.



Furaneol has a significant impact.
Linalool can also have a slight impact.

Influence of flavors and essential oils (2)

- EXBERRY® Shade Mandarin has an orange cloudy color shade in beverages. Its crystalline pigments (carotenoids) are insoluble in water.
- These crystals can be dissolved in oil (e.g. in citrus oil in a flavoring), resulting in a more yellow color shade.
- High shear forces (intensive mixing, homogenization) or pasteurization promote this process.



- Crystalline form → No solubility in water → ORANGE appearance
- Carotenoids dissolve in oil → YELLOW-ORANGE appearance

Influence of other ingredients

Proteins

- Haze can develop following interaction between EXBERRY® and proteins in beverages

Minerals

- Some metals can form complexes with anthocyanins and influence color stability.
- The most common ones are copper (Cu), iron (Fe), magnesium (Mg), tin (Sn) and potassium (K)

Flavorings and botanical extracts

- Certain flavorings and botanical extracts may also cause interactions with EXBERRY®

2

Tips and tricks on how to optimize EXBERRY® performance

GROWING COLORS EXBERRY®

Tip 1: Choose an adequate EXBERRY® dosage!

- The higher the EXBERRY® concentration, the more intense the color.

0.020 % 0.033 % 0.050 %

EXBERRY® Shade
Brilliant Pink

The more intense the color, the lower the light penetration and the better the color protection!

Test if increasing the EXBERRY® dosage by 20-30 % will solve stability issues!

Always evaluate color stability, especially for very low EXBERRY® concentrations!

Color quality: Non-adapted dosage

Product	EXBERRY® Shade Red A	EXBERRY® Shade Red B	EXBERRY® Shade Red C
Concentrate of…	Carrot, blackcurrant	Carrot, blackcurrant	Carrot, blackcurrant
Dosage	0.05 %	0.05 %	0.05 %

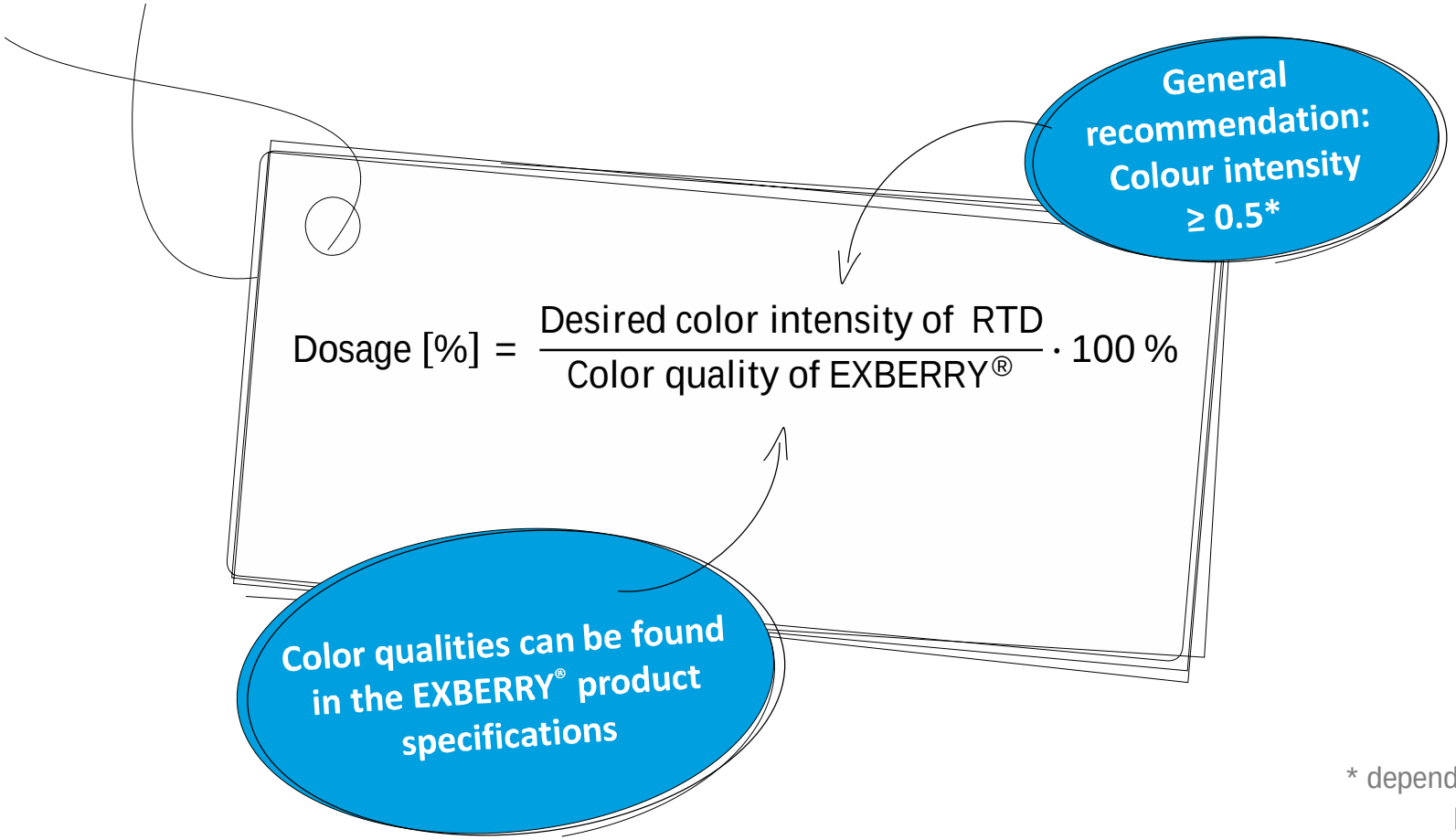
The more intense the color, the lower the light penetration and the higher the color retention!

Sunlight Test
(2592 kJ/m²)

47 % 48 % 67 %

Color retention

Color quality: Adapted dosage (1)



* depending on EXBERRY® product, recipe, packaging and storage conditions

Color quality: Adapted dosage (2)

EXAMPLE

$$\text{Dosage [\%]} = \frac{0.5}{\mathbf{300}} \cdot 100\,\% = 0.17\,\%$$

$$\text{Dosage [\%]} = \frac{0.5}{\mathbf{500}} \cdot 100\,\% = 0.10\,\%$$

$$\text{Dosage [\%]} = \frac{0.5}{\mathbf{1000}} \cdot 100\,\% = 0.05\,\%$$

Different dosages, but same color intensity in RTD

Color qualities from specification

EXBERRY® Shade Red A	EXBERRY® Shade Red B	EXBERRY® Shade Red C
300	500	1000

Color quality: Adapted dosage (3)

Product	EXBERRY® Shade Red A	EXBERRY® Shade Red B	EXBERRY® Shade Red C
Concentrate of…	Carrot, blackcurrant	Carrot, blackcurrant	Carrot, blackcurrant
Color quality	300	500	1000
Adapted dosage	0.17 %	0.10 %	0.05 %

Always compare EXBERRY® products by adapting the dosage to the same color intensity!

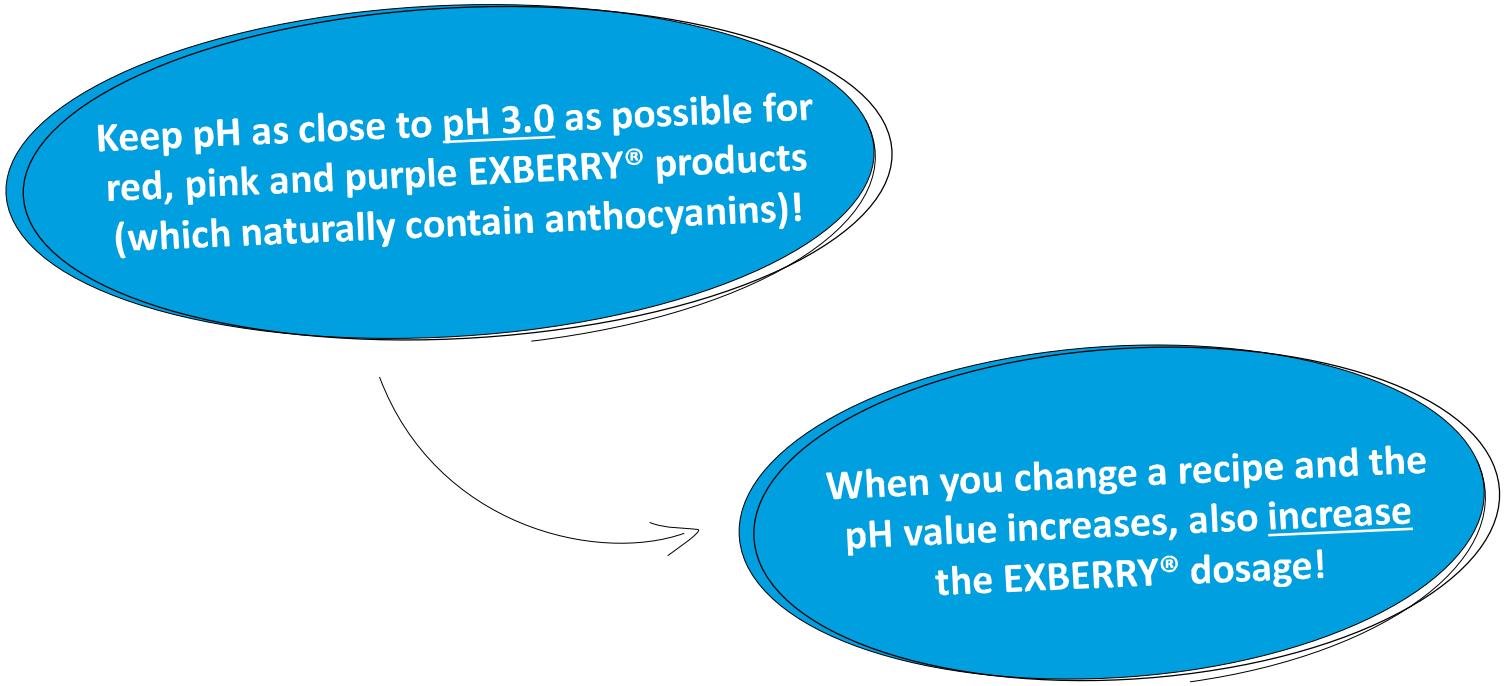
Sunlight Test
(2592 kJ/m²)

63 %	62 %	65 %

Color retention

Tip 2: Choose an adequate pH value or adapt dosages! (1)

Red, pink and purple EXBERRY®



Tip 2: Choose an adequate pH value or adapt dosages! (2)

Red, pink and purple EXBERRY®

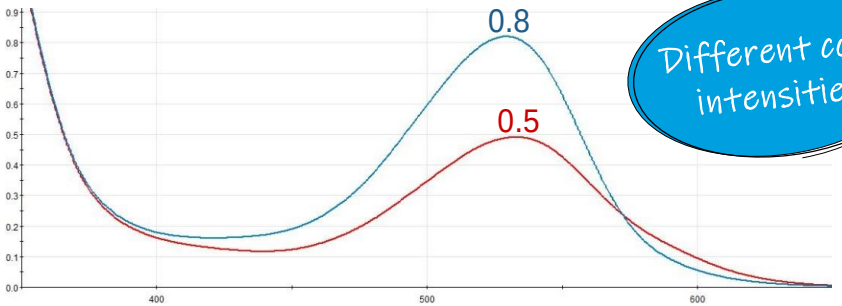
Example: Influence of pH value on color intensity

EXBERRY® Shade Brilliant Pink

pH 3.0 pH 4.0

0.053 % 0.053 %

Different color shades



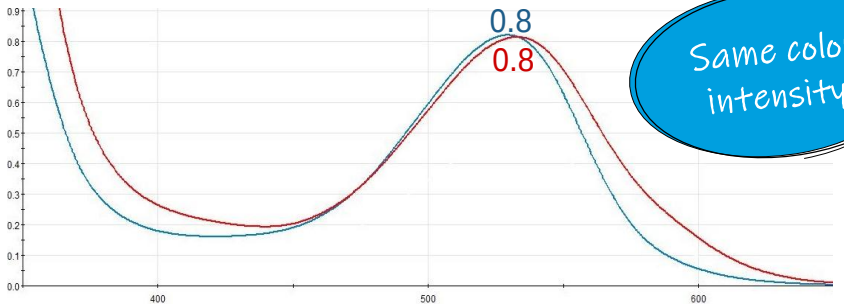
Different color intensities

EXBERRY® Shade Brilliant Pink

pH 3.0 pH 4.0

0.053 % 0.093 % (+ 76 %)

Different color shades



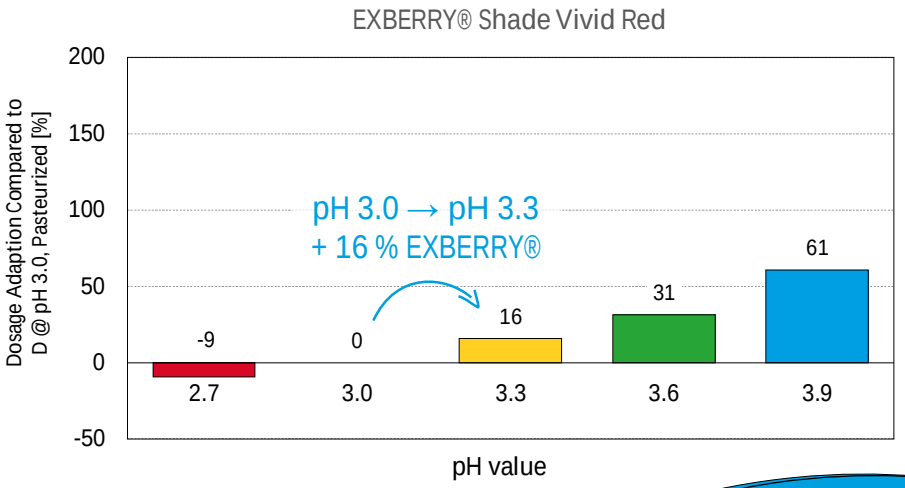
Same color intensity

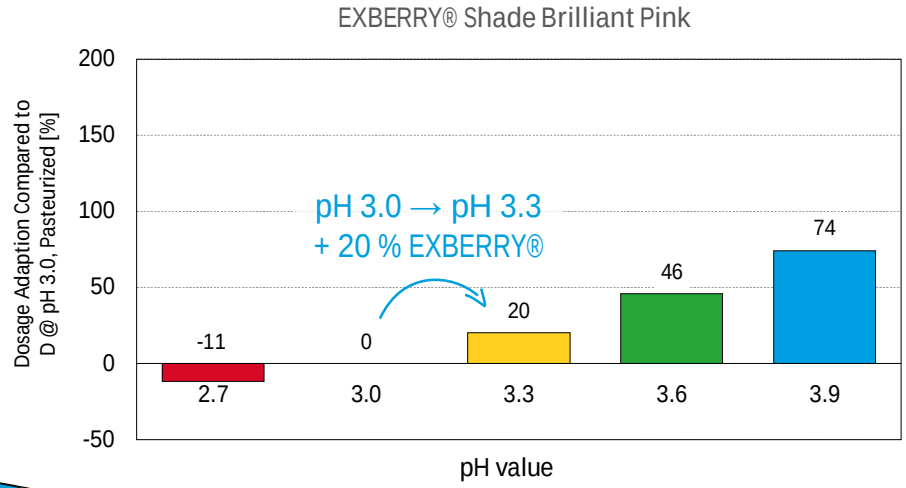
Tip 2: Choose an adequate pH value or adapt dosages! (3)

Red, pink and purple EXBERRY®

Complete study

Example: Dosage adjustments for equal color intensities after pasteurization





Test if increasing the EXBERRY® dosage by 20-30 % will solve stability issues!

Tip 3: Make sure your water quality is consistent!

Water composition can influence the pH value of a drink and therefore the color shade of red, pink and purple EXBERRY® products (which naturally contain anthocyanins)!

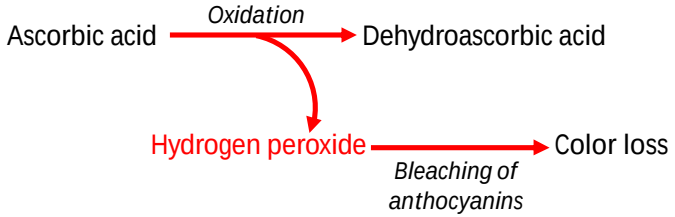
"acid neutralizing capacity"

Study running on influence of mineral water composition on color stability

- Adjust the pH value when you alter the water quality.
  - Ensure that the water quality during product development is like the one in the factory.
  - Ensure that the water quality in the plant is consistent over time (recipe transfer from one factory to another).

Tip 4: Best practice when working with ascorbic acid (1)

- Ascorbic acid oxidation products cause irreversible bleaching of anthocyanins.



➢ When using ascorbic acid and anthocyanin-based EXBERRY® in a drink:

1. Keep the technological necessary dose of ascorbic acid as low as possible (GMP).
2. Avoid very low EXBERRY® levels.
3. Remember that ascorbic acid can also be added via fruits (e.g. acerola, citrus).
4. Avoid high vitamin C claims. Ascorbic acid is often overdosed to ensure that the claimed dosage is still present at the expiration date.
5. Shorter shelf lifes are preferred to longer ones.

➢ Heat, time and oxygen level are the main factors promoting color degradation.

➢ Vegetable based EXBERRY® concentrates are more stable than fruit juices (e.g. elderberry).

Tip 4: Best practice when working with ascorbic acid (2)

- Ascorbic acid protects carotenoid-based EXBERRY® from oxidation.
  - Carotenoid losses are influenced by both storage temperature and light exposure and are driven by oxidative reactions.
  - The addition of ascorbic acid, which degrades via an oxygen-consuming pathway, has a protective effect on carotenoids.

➢ When using ascorbic acid and carotenoid-based EXBERRY® products in a drink:

1. Ascorbic acid is needed, especially when using clear packaging or storage temperatures are high.
2. The amount of ascorbic acid depends on factors as selected EXBERRY® product, oxygen level and intended shelf life.
3. Recommended dosage levels for EXBERRY® Shade Yellow and Shade Mandarin: 200-300 ppm
4. Reducing the amount of oxygen in the beverage (e.g. modified atmosphere by nitrogen flush or carbonization, oxygen scavengers, low head space, hot filling) might significantly reduce the amount of needed ascorbic acid.

Planned study on influence of oxygen on color stability.

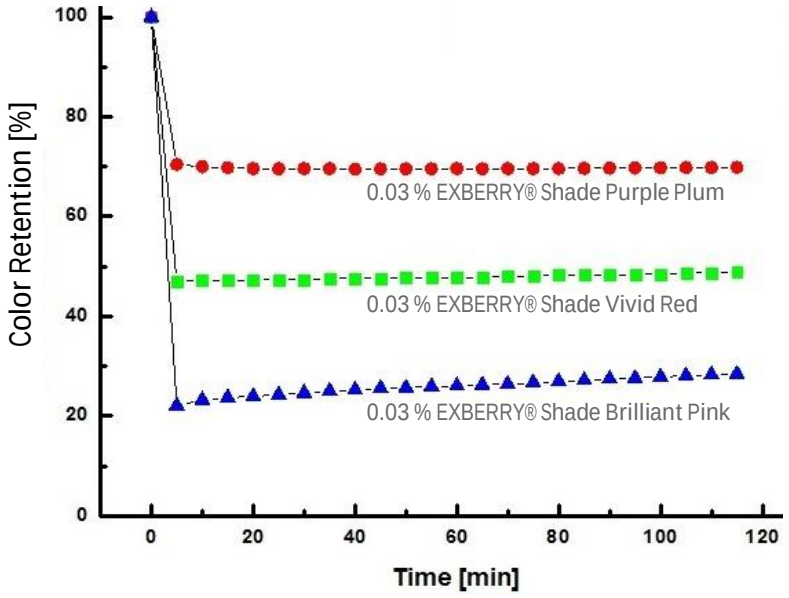
Tip 5: Best practice when working with sulphur dioxide (1)

Sulphur dioxide can lower the color intensity of red, pink and purple EXBERRY® products (which naturally contain anthocyanins)!

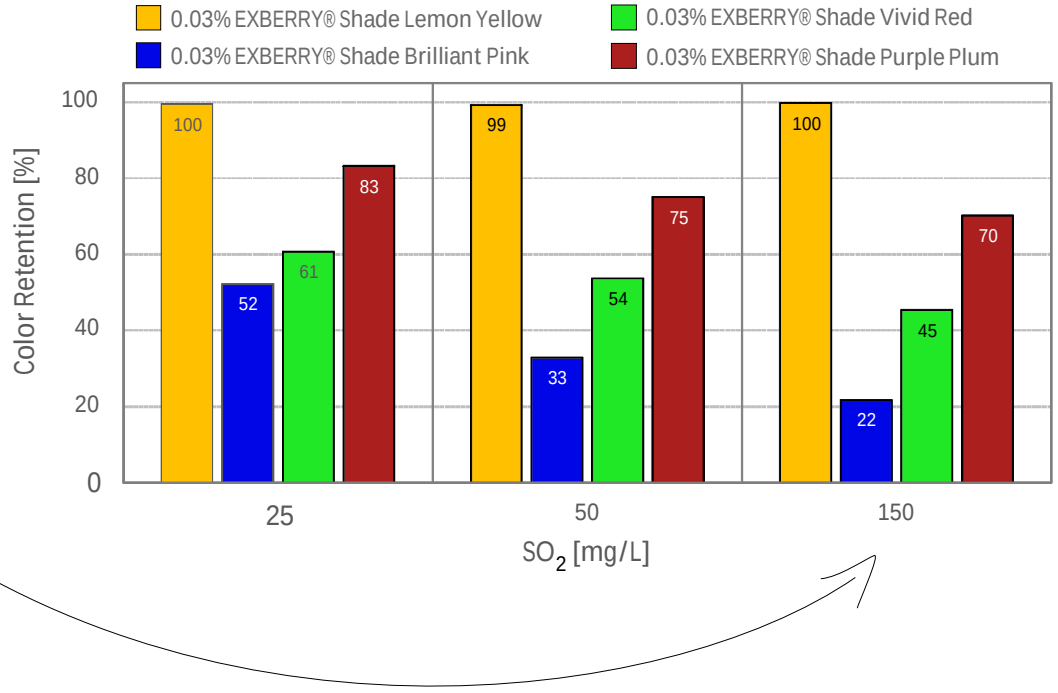
- Free SO_2 forms a colorless complex with anthocyanins.
- Different EXBERRY® raw materials show different affinities to react with SO_2.
- The most crucial factor for is the concentration of EXBERRY®. Initial loss can be mitigated by increasing the dosage.
- Reducing the amount of SO_2 will lead to a higher initial color intensity.

Tip 5: Best practice when working with sulphur dioxide (2)

- Impact of SO_2 addition (150 ppm) on color intensity of different EXBERRY®

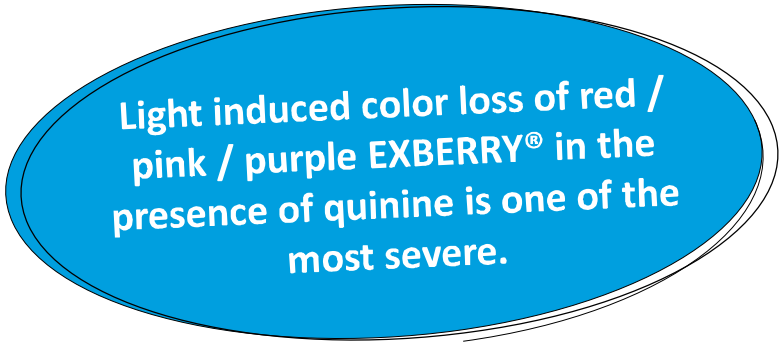


- Impact of increasing SO_2 levels on the color intensity of different EXBERRY® products.



Tip 6: Best practice when working with quinine (1)

- The quantity of quinine has a significant influence on color stability
- Higher EXBERRY® dosages show better color stability in the presence of quinine
- The degradation reaction is light driven so interactions should be minimum in canned products but substantial in clear bottles when exposed to store light or UV light



Tip 6: Best practice when working with quinine (2)

Observations:

- Store light and sunlight testing over-accelerate color loss in samples containing quinine:
  - Effect of UV light
  - Effect of incandescent light + heat
- Due to non-correlation of quinine containing samples, store light and sunlight testing is not advised to predict color stability in tonic waters.

Study running on influence of non-quinine based bitter flavors and quassia extract on EXBERRY®

Performance of red, pink and purple EXBERRY® products under different ingredient impacts

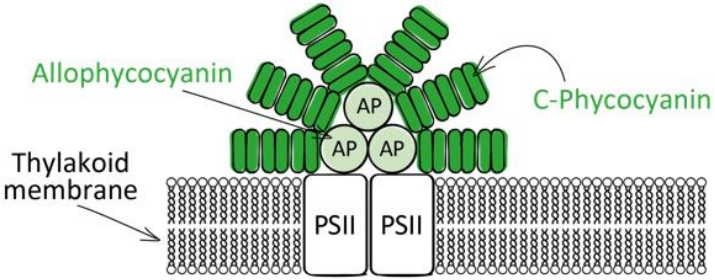
	Lower colour retention ✗ → Higher colour retention ✓				
pH > 3.2	EXBERRY® Shade Fruity Red	EXBERRY® Shade Brilliant Pink	EXBERRY® Shade Rubescent Red	EXBERRY® Shade Vivid Red	EXBERRY® Shade Purple Plum
Ascorbic Acid	EXBERRY® Shade Fruity Red	EXBERRY® Shade Vivid Red	EXBERRY® Shade Rubescent Red	EXBERRY® Shade Brilliant Pink	EXBERRY® Shade Purple Plum
SO_2	EXBERRY® Shade Fruity Red	EXBERRY® Shade Brilliant Pink	EXBERRY® Shade Rubescent Red	EXBERRY® Shade Vivid Red	EXBERRY® Shade Purple Plum
Quinine	EXBERRY® Shade Fruity Red	EXBERRY® Shade Vivid Red	EXBERRY® Shade Purple Plum	EXBERRY® Shade Rubescent Red	EXBERRY® Shade Brilliant Pink

Select EXBERRY® products with strongest performance in the presence of interactive ingredients

Tip 7: Best practice when working with Blue and Green (1)

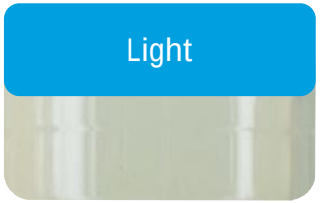
Considerations for blue and green NABs

- Spirulina's pigment phycocyanin has a protein backbone
- Several ingredients, recipe parameters, process and storage conditions can lead to color loss and/or aggregation

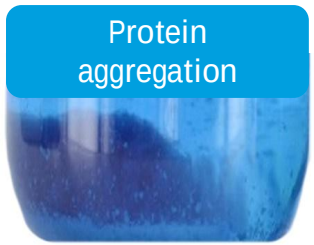


Challenges

Color loss in the presence of:



Stabilization issues:



Check out GNT's patented technical solution!

Tip 7: Best practice when working with Blue and Green (2)

Considerations for blue and green refrigerated smoothies and juices:

- Keep the processing conditions short to minimize temperature impact.
- Some color loss is expected. EXBERRY® should be overdosed (typically at 150 %).
- Sedimentation depends on the beverage composition.
- Consider increasing the viscosity to reduce sedimentation and/or homogenize to ensure a consistent particle size.
- Background color is important when creating a blue product. Make sure the base is as white/colorless as possible.

EXBERRY® Shade Lime Green	EXBERRY® Shade Lime Green	EXBERRY® Shade Lime Green	EXBERRY® Shade Lime Green	EXBERRY® Shade Blue – HP	EXBERRY® Shade Blue - HP
0.24 %	0.48 %	1.5 %	2.96 %	1.08 %	2.13 %

Smoothie base ingredients:

- Pineapple Juice (31 %), Apple Juice, Banana Purée (20 %), Apple Purée, Coconut Cream (5 %), Lemon Juice.

Technical parameters:

- pH value: 3.6
- °Brix: 14.4
- Processing conditions: 90 °C for 10 s

Check out our Smoothies and Juices Color Guide

Tip 8: Best practice when working with cloudy EXBERRY® (1)

EXBERRY® Shade Mandarin

- Without the addition of a suspension agent, EXBERRY® Shade Mandarin will fall out completely within few days.
- Xanthan gum is recommended to be added to the beverage formula:
  - Xanthan must be hydrated with most of the recipe water.
  - Once xanthan is hydrated, it must be blended with EXBERRY® Shade Mandarin first. Then all other ingredients should be added.
  - Recommended final dosage is xanthan is 0.01-0.03 %. Higher levels will impart mouthfeel and increase viscosity. Maximum recommended use level for syrups is 0.05 %.
  - Viscosity decreases with mixing or shaking and will increase when it is stationary, making xanthan a great suspension agent.
- Ascorbic acid addition might be necessary to improve color stability.

0.13 % EXBERRY® Shade Mandarin

No hydrocolloid
3 days

0.03% Xanthan Gum
2 months

Tip 8: Best practice when working with cloudy EXBERRY® (2)

EXBERRY® Shade Yellow

- Yellow carotenoid-based EXBERRY® products need a stabilizing system to prevent defects over shelf life. Those can be:
  - Aggregation, where large clusters form, often floating throughout the beverage volume
  - Sedimentation, where solids sink down to the bottom
  - Neck-ringing, where oil floats to the top of the beverage to form a ring

Option 1:

EXBERRY® Shade Yellow - Cloudy Powder

- Spray dried with Gum Arabic (→ hydrocolloid with emulsifying properties)
- Minimized ringing properties
- Can be used on its own if some sedimentation is acceptable
- Xanthan can be added to minimize sedimentation
- Dry blending (e.g. sugar) recommended for easier dispersion and hydration during formulation

Tip 8: Best practice when working with cloudy EXBERRY® (3)

EXBERRY® Shade Yellow

Option 2:

EXBERRY® Shade Yellow*

- First step should be making a “color compound”
  (45 % water + 5 % Gum Arabic* + 50 % EXBERRY®)
  to delay ring formation if this is a critical quality feature
- Color compound requires homogenization
  (240 bar, 3 passes, target size: D50 < 0.5 µm)
- Xanthan should be added to reduce sedimentation

0.07 % EXBERRY® Shade Yellow

No hydrocolloid
7 days

Gum Arabic
2 months

Gum Arabic + Xanthan gum
6 months

*Other hydrocolloids can be used

Tip 9: Consider background color and juice browning!

Fruit juices or background color in general will have a significant impact on the overall color shade.

Clear Base

0.05% EXBERRY® Shade Brilliant Pink

- The overall color shade is always the sum of background color plus EXBERRY®.
- Fruit juice color is often not standardized and might change from lot to lot.
  - Ensure the EXBERRY® dosage is high enough to mitigate the color shift.
- Browning:
  - Consider how the base color from fruit will brown or yellow over shelf life.
  - Ascorbic acid browning can also be an issue.
  - EXBERRY® can be used to cover browning to a certain extent.

30% Apple Juice

0.05% EXBERRY® Shade Brilliant Pink

3

Summary

GROWING COLORS EXBERRY®

Conclusion

- Every beverage is unique! Color stability needs to be assessed with reference to its properties.
- There are INTERNAL factors (like pH value and ingredients) and EXTERNAL factors (like packaging, processing and storage conditions) that need to be considered.
- The selection of the right EXBERRY® products and dosages are important to get the desired color shade and color stability over shelf life.

GROWING COLORS

EXBERRY®

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