Antiplasticizing effect of water in cereal products

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Introduction

Water affects mechanical properties of food which depend on the chemical composition, microscopic structure and the method of manufacturing of the product. Generally it is observed that increasing water content in brittle, crunchy materials changes its rheological properties to visco-elastic and plastic. Hence, water is regarded as a plasticizer promoting movement of structural elements one in respect to others under the influence of force.

Introduction

For years it was recognized that for many foods maximum values for certain mechanical properties occur at specific water contents or water activities (Kapsalis et al., 1970; Reidy and Heldman, 1972; Bourne, 1986; Halek et al., 1989; Fontanet et al., 1997; Roudaut et al., 1998; Lewicki et al., 1998; Seow et al., 1999). This antiplastisizing effect of water is not fully understood, and few hypotheses are proposed:

- increased crystallinity,
- “hole-filling”- decrease of free volume,
- specific interactions with polymers,
- relaxation of high energy regions.

Methods

Samples of flat extruded wheat, rye, corn-buckwheat bread with dimensions 120x54x7mm, crackers with dimensions 48x40x5mm, and corn flakes were stored in desiccators at 25^0C at prescribed relative humidities of air. Water activities were in the range 0.01 to 0.90.

Water activity (a_w) of all samples was measured with Hygroskop DT 2 (Rotronic) with the accuracy ± 0,001, at 25^0C.

Water content in equilibrated samples was measured by drying according to Polish Standard PN-84/A-86361.

Methods

Samples of flat extruded bread and crackers were subjected to three-point breaking process done in a Zwick 1445 Machine. Loading was done with the cross-head speed 20 mm/min.

Corn flakes were piled one over the other and pressed with a ball 6 mm in diameter in Texturometer TA XT2i/25 (Stable Micro Systems) at ball speed 60 mm/min.

Fig. 1. Sample in the Zwick loading machine

Methods

Work [J] was calculated as the area under the deformation curve, force vs. time.

$$W = v \int_0^t F(t)\,dt$$

Breaking stress, [Pa]

$$\sigma_r = F_{max} \cdot \frac{3L}{2eh^2}$$

F(t) – force in the function of time [N];

v - cross-head velocity (20 mm/min);

L - distance between supports [m];

0.052 for breads

0.040 for crackers

e – width of the sample [m];

h – thickness of the sample [m];

F_{max} – maximum force, [N]

Results

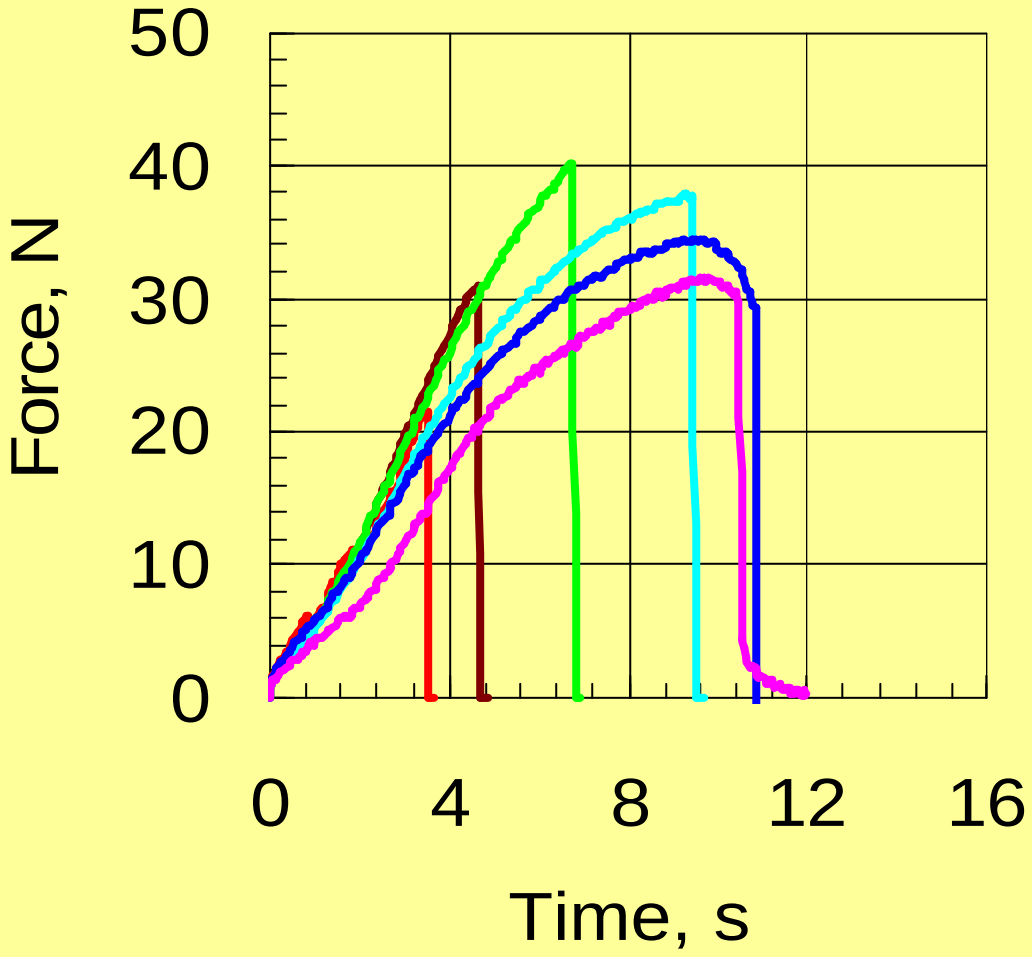


Fig. 2. Deformation curves of flat extruded wheat bread

1 - a_w = 0.041;

2 - a_w = 0.278;

3 - a_w = 0.464;

4 - a_w = 0.669;

5 - a_w = 0.693;

6 - a_w = 0.750

Results

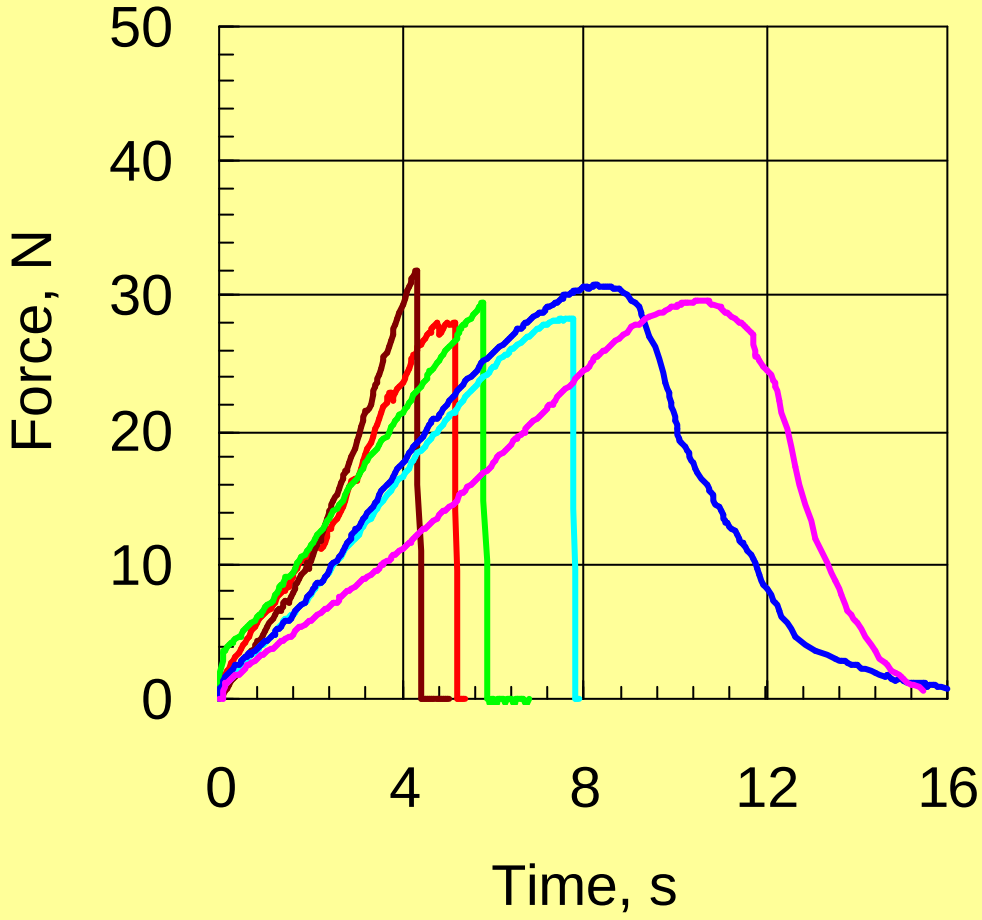


Fig. 3. Deformation curves of flat extruded rye bread

1 - a_w = 0.037;

2 - a_w = 0.257;

3 - a_w = 0.429;

4 - a_w = 0.693;

5 - a_w = 0.712;

6 - a_w = 0.750

Results

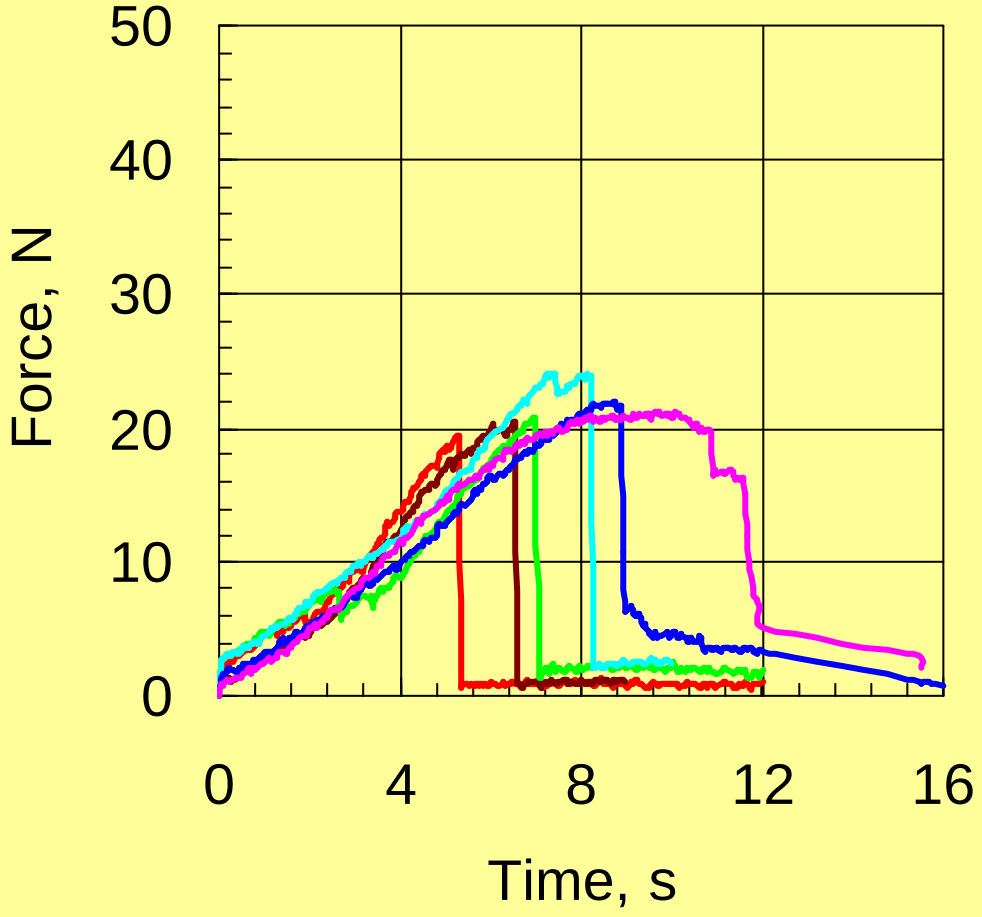


Fig. 4. Deformation curves of flat extruded corn-buckwheat bread

1 - a_w = 0.288;
2 - a_w = 0.352;
3 - a_w = 0.430;
4 - a_w = 0.530;
5 - a_w = 0.625;
6 - a_w = 0.700;

Results

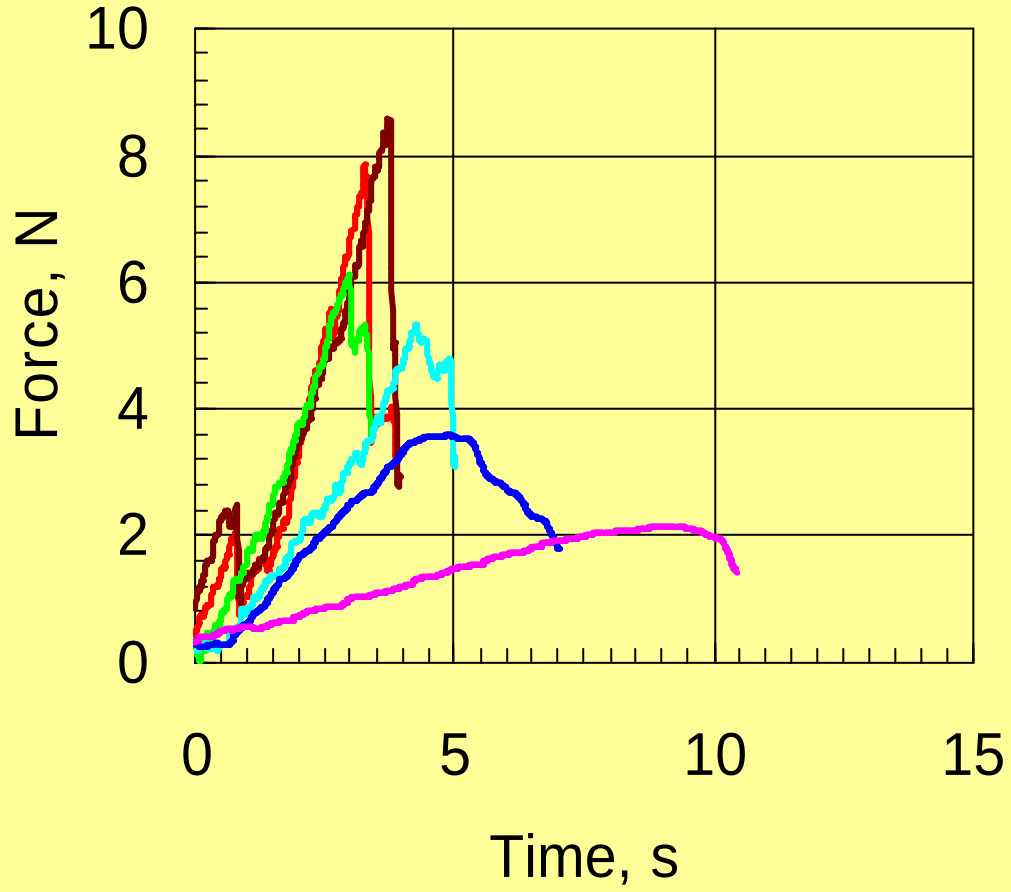
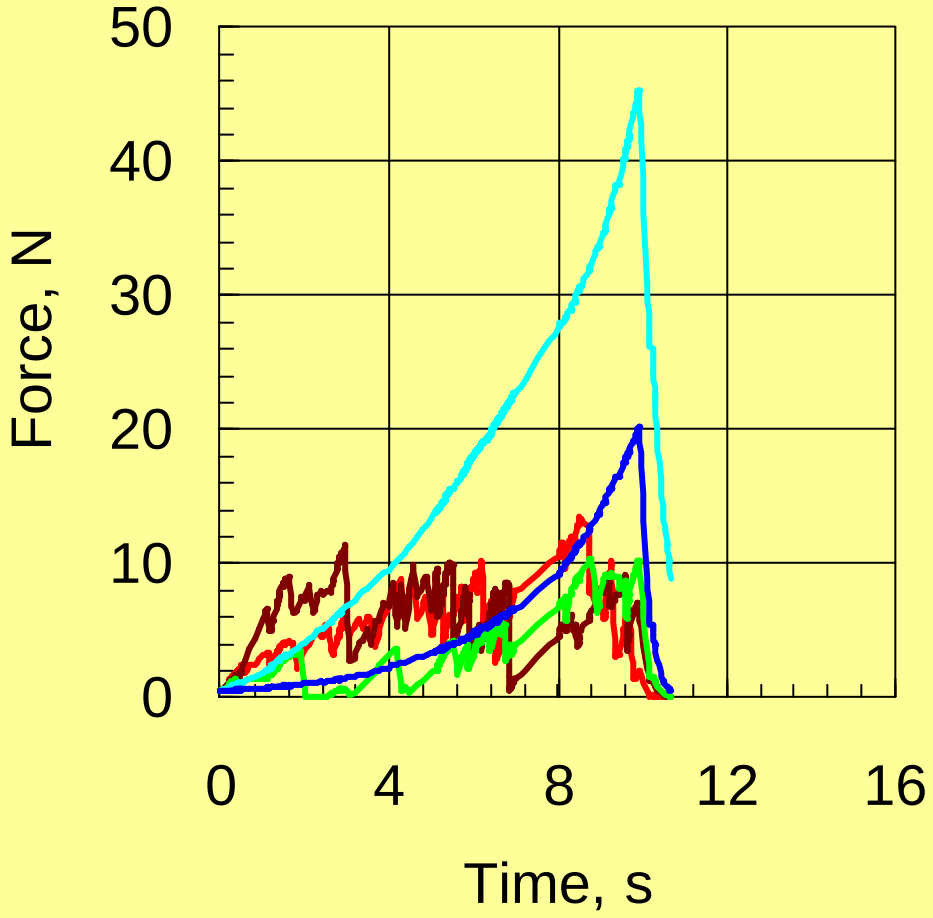


Fig. 5. Deformation curves of crackers

1 - a_w = 0.214;
2 - a_w = 0.305;
3 - a_w = 0.412;
4 - a_w = 0.518;
5 - a_w = 0.616;
6 - a_w = 0.730

Results



Rys. 6. Deformation curves of corn flakes

1 - a_w = 0.209;
2 - a_w = 0.299;
3 - a_w = 0.516;
4 - a_w = 0.639;
5 - a_w = 0.713;

Results

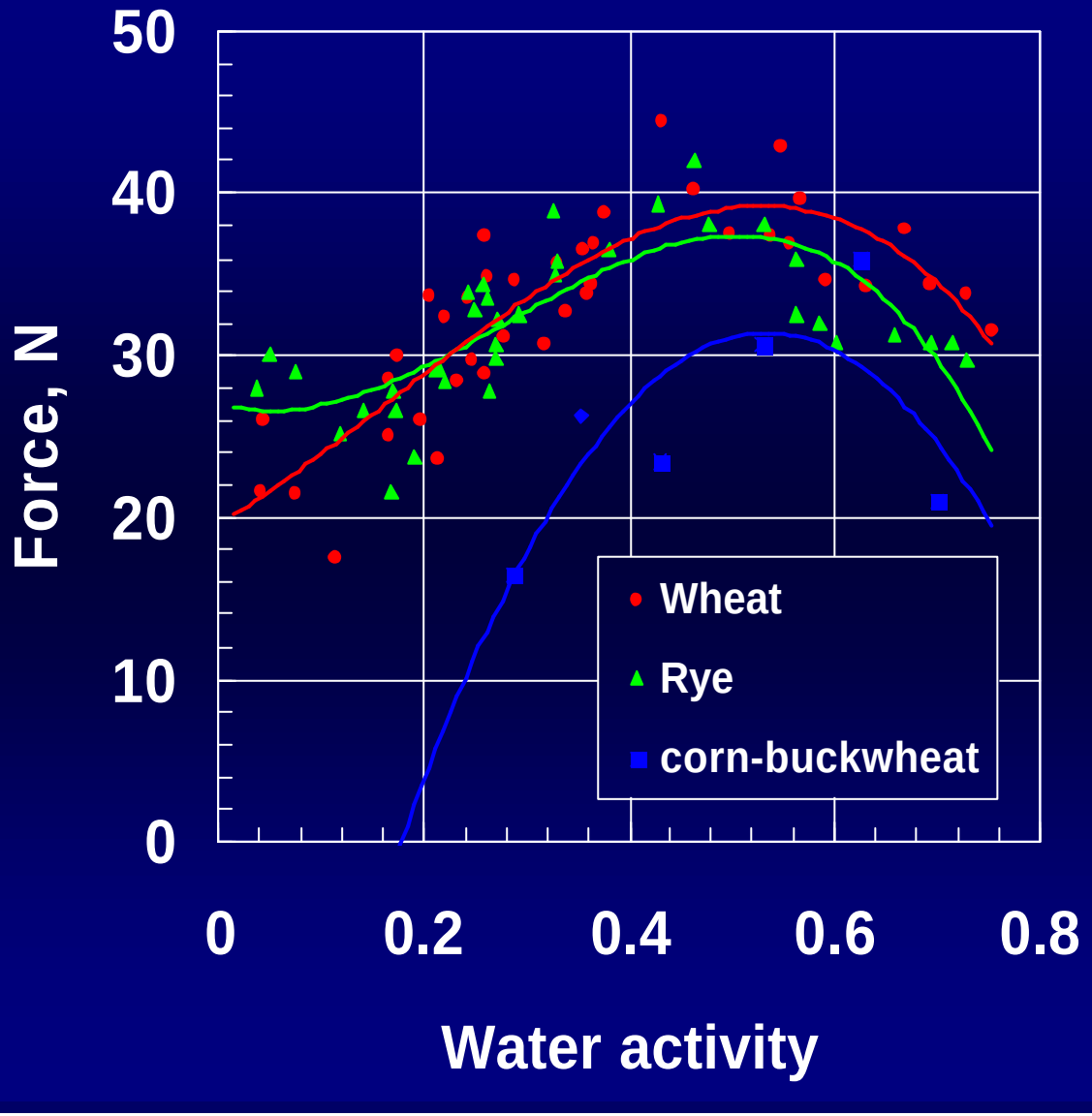


Fig. 7. Relationship between breaking force and water activity for flat extruded breads

Results

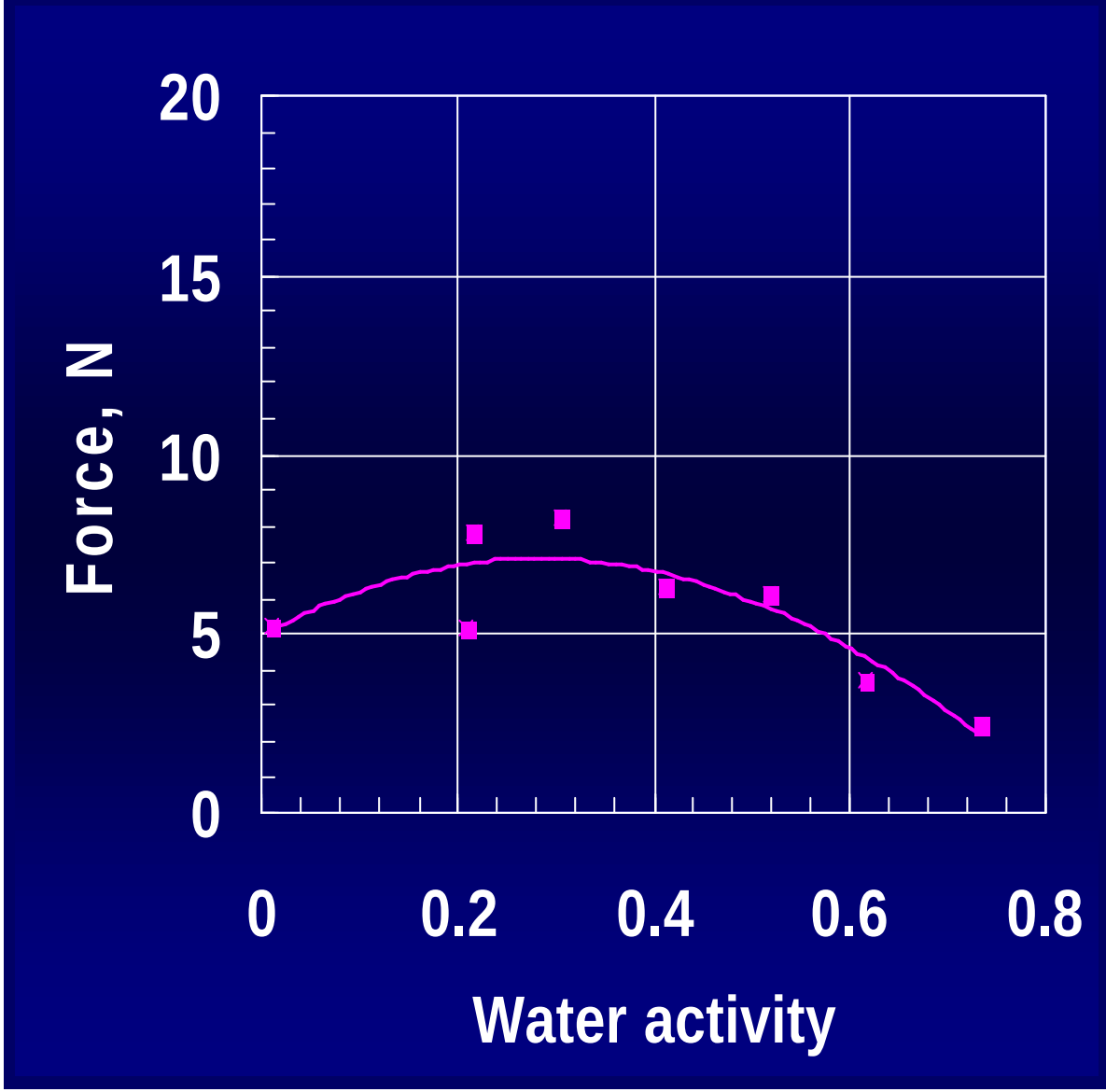


Fig. 8. Relationship between breaking force and water activity for crackers

Results

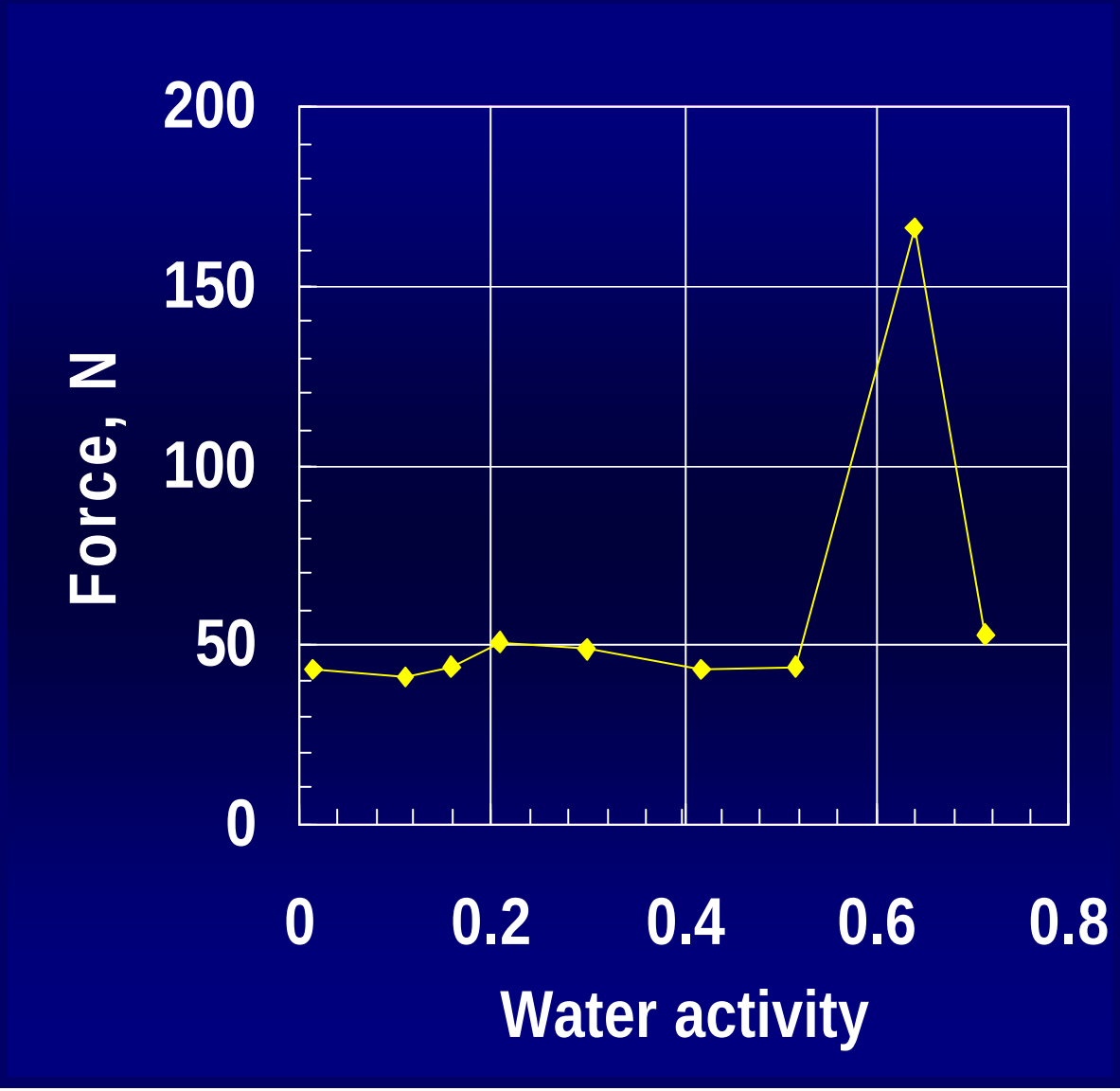


Fig. 9. Relationship between breaking force and water activity for corn flakes

Results

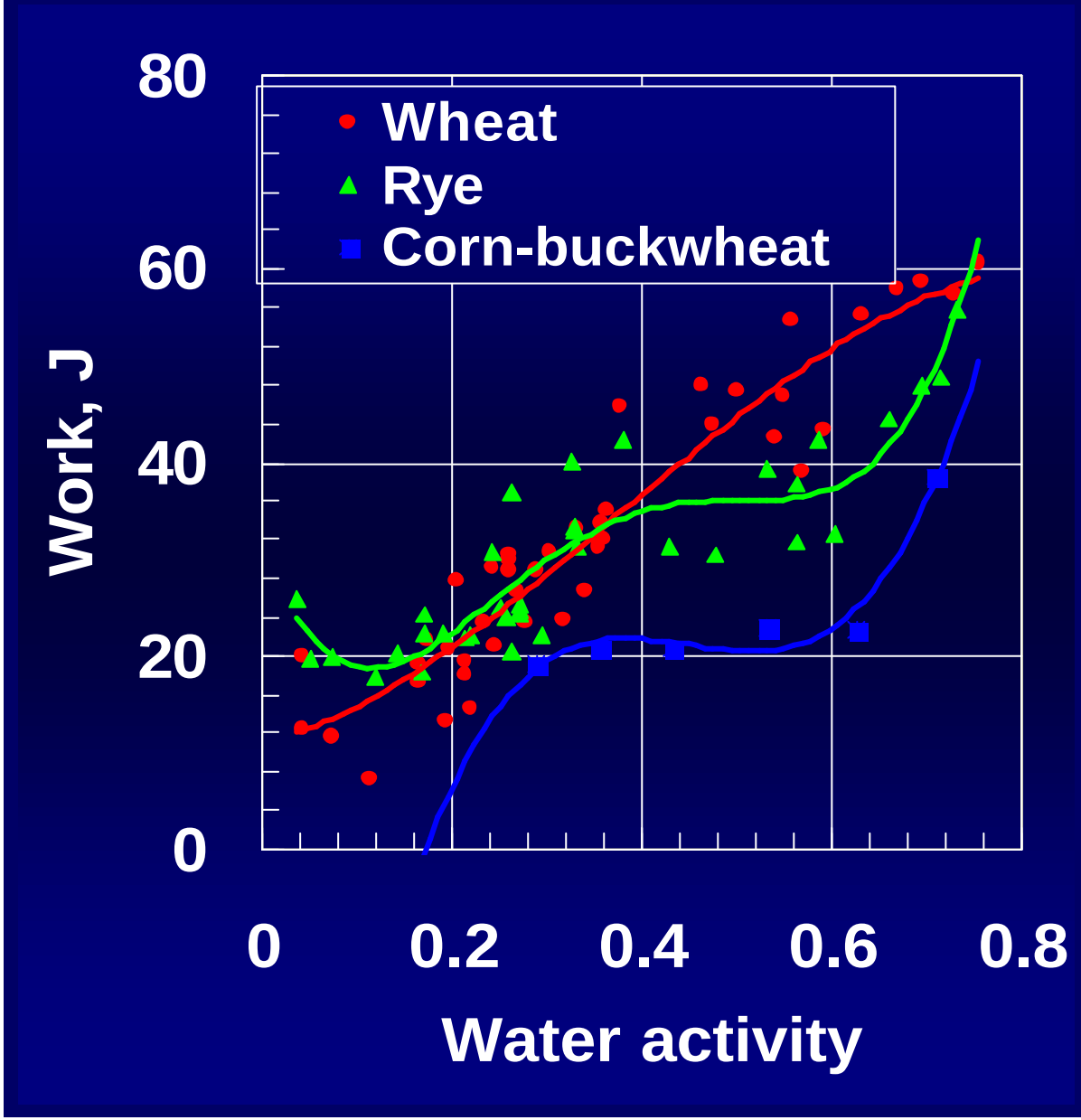


Fig.10. Relationship between breaking work and water activity for flat extruded breads

Results

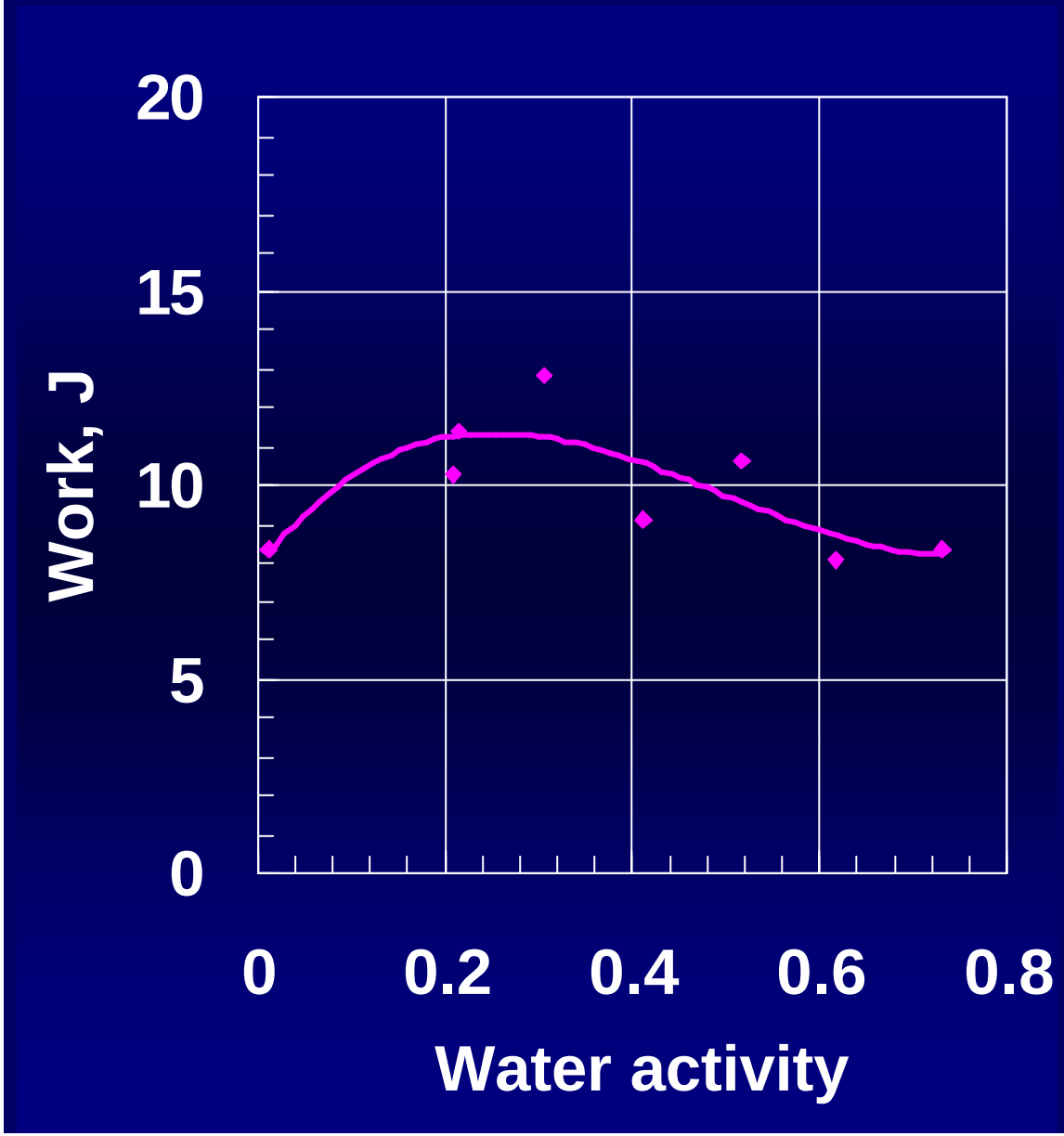


Fig. 11. Relationship between breaking work and water activity for crackers

Results

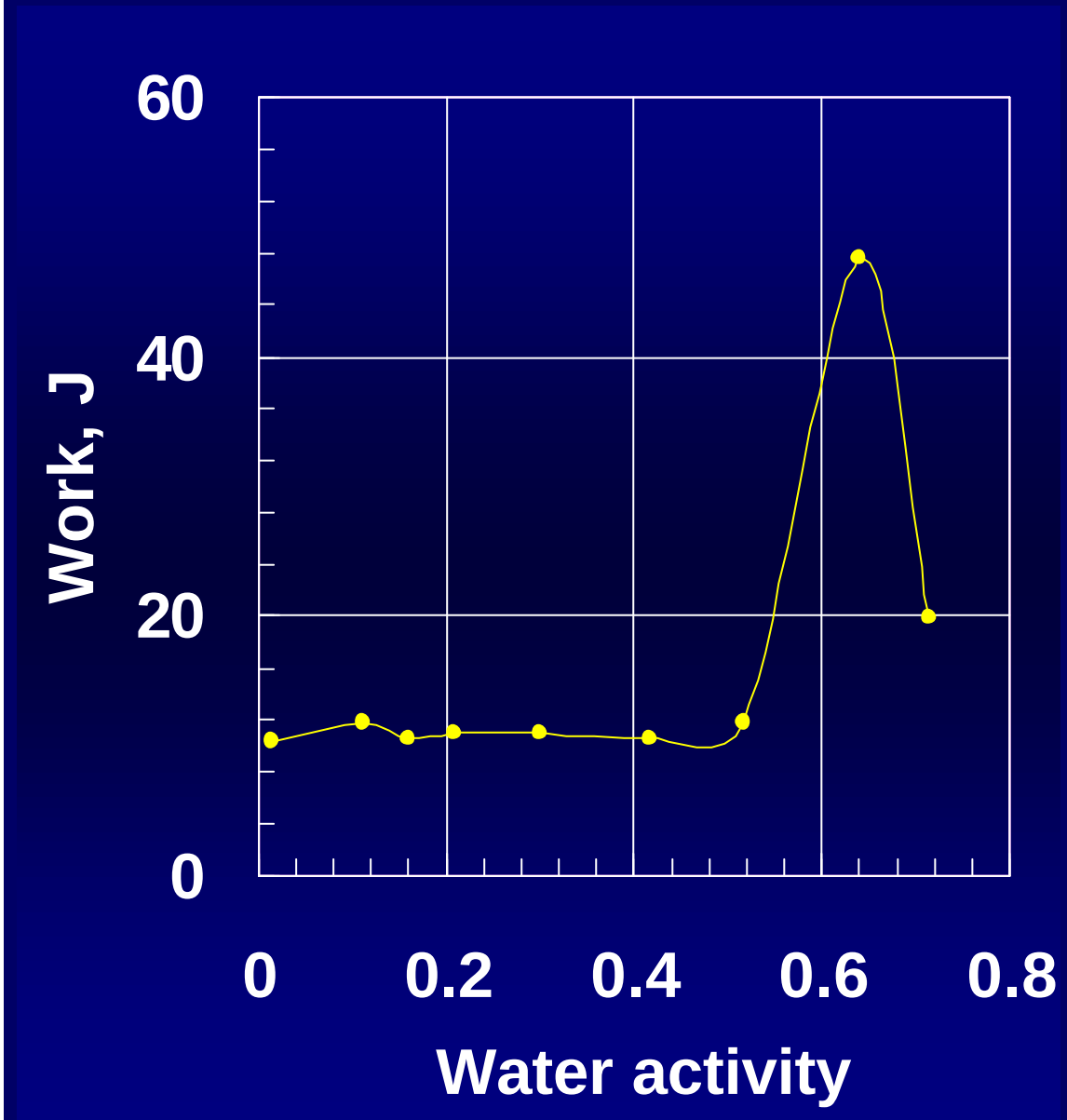


Fig. 12. Relationship between breaking work and water activity for corn flakes

Results

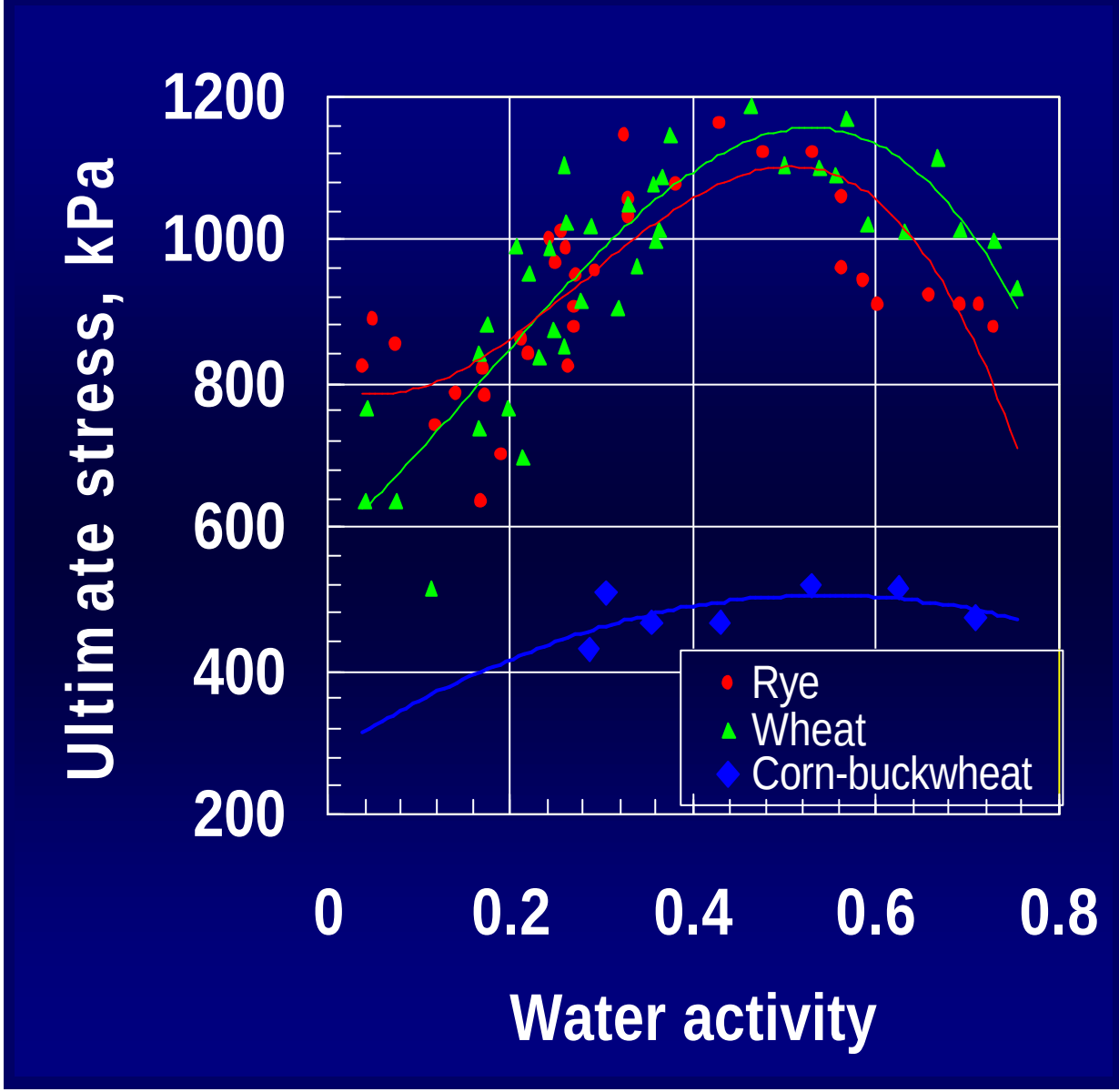


Fig. 13. Relationship between breaking stress and water activity for flat extruded breads

Results

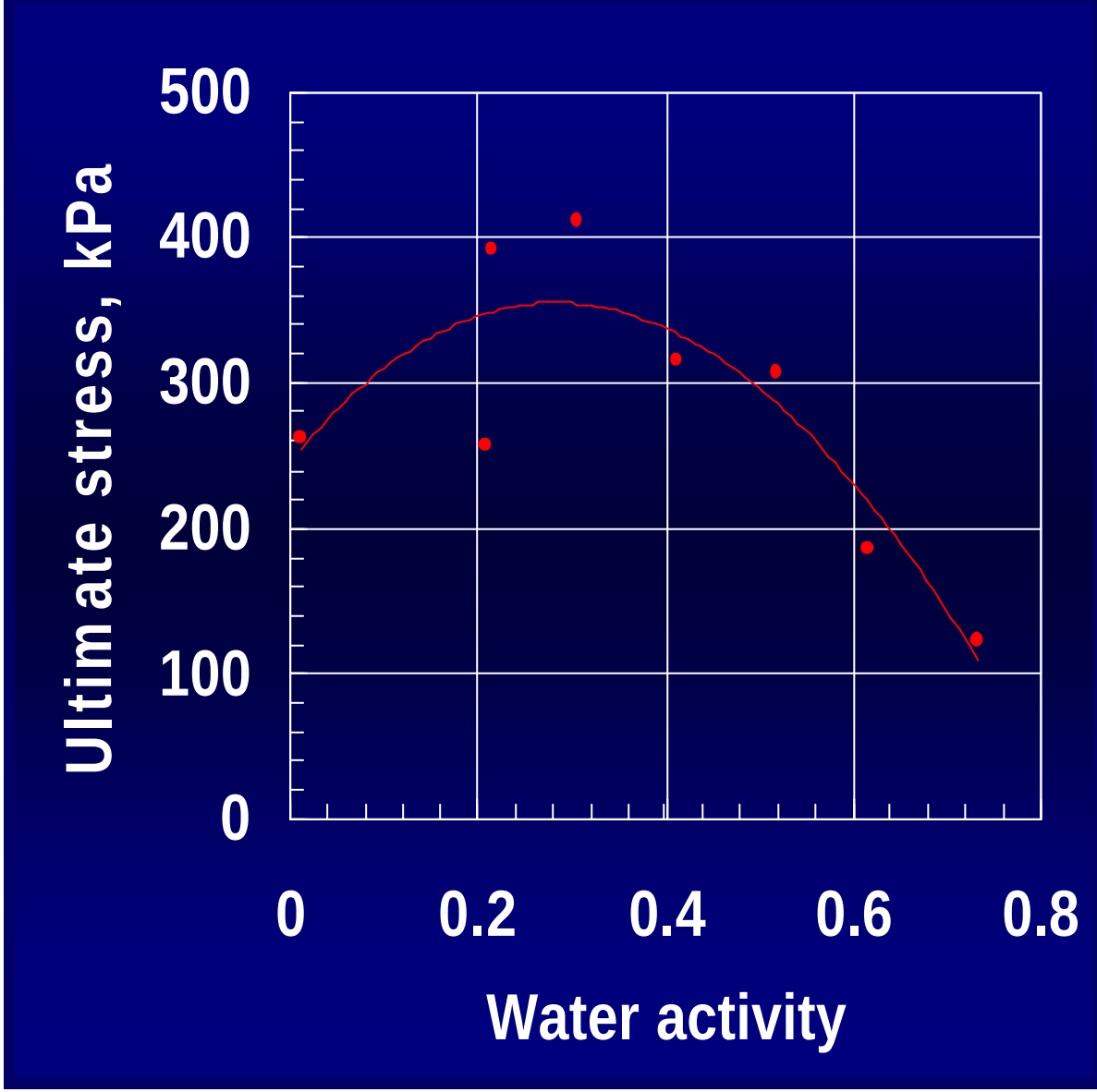


Fig. 14. Relationship between breaking stress and water activity for crackers

Conclusions

1. Influence of water activity on mechanical properties of cereal products is very pronounced and strongly dependent on the kind of analyzed material.

2. Each analyzed product shows a critical water activity below which water antiplasticizes material and increases its mechanical resistance. Above that water activity water plasticizes material.

3. Critical water activity can be regarded as a property of cereal based products.

Thank you very much for your attention