

**Maize kernel translucency measurement by Image Analysis and its relationship to
vitreousness and dry milling performance**

by

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I declare that the dissertation herewith submitted for the PhD Food Science degree at the University of Pretoria, has not previously been submitted by me for a degree at any other university.

ABSTRACT

MAIZE KERNEL TRANSLUCENCY MEASUREMENT BY IMAGE ANALYSIS AND ITS RELATIONSHIP TO VITREOUSNESS AND DRY MILLING PERFORMANCE

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A rapid non-destructive Image Analysis (IA) technique was developed for the determination of maize kernel endosperm vitreousness. Kernels were analysed using a Leica Q-Win Q500 IW-DX Image Analyser fitted with Leica Q-Win software and connected to a Sony XC-75 CCD camera. Kernel translucency measurements were optimised by using a light system that involved positioning whole kernels on top of a mask containing round illuminated areas (circles), smaller than the projected areas of the kernels, allowing light to shine through the kernels only. Correction factors allowing for constant illumination of kernels were developed to adjust for kernel size variation in relation to constant light area. Similarly, a correction factor for the effect of kernel thickness on detected translucency values were developed.

Significant correlations were found between corrected translucency values and vitreous and opaque endosperm yields as determined by hand dissection. These were: translucency as a percentage of the whole kernel and vitreous endosperm (mass %) (Translucency 1), $r = 0.77$, $p < 0.00001$, and Translucency 1 and opaque endosperm (mass %), $r = -0.72$, $p < 0.00001$ for white maize. Similar correlations were found for translucency as a percentage of endosperm (Translucency 2). Correlation coefficients increased significantly after kernel thickness corrections. Significant negative correlations were also found between corrected translucency values and Floating Number. For yellow maize, Translucency 1 correlation coefficients was $r = 0.78$,

$p < 0.00001$ and $r = -0.71$, $p < 0.00001$ respectively with similar correlations for Translucency 2. Correlations were obtained after applying both correction factors for exposure and thickness.

The IA technique was evaluated for predicting the yield of vitreous endosperm products during dry maize milling in laboratory and industrial-scale milling trials. Significant positive correlations were found between corrected translucency values and yields of milling products from vitreous endosperm. Experiments using a laboratory-scale experimental roller milling test without a degerming stage produced the following correlations: between Translucency 1 and semolina yield (mass %), 0.74, $p < 0.001$ and Translucency 2 and semolina yield (mass %), 0.70, $p < 0.001$. For industrial-scale milling, a Bühler industrial-scale maize mill (3 tons per hour) was used. The correlation between Translucency 1 and extraction at degermer (degermer overtail yield) was 0.93, $p < 0.0001$. There was a similar correlation for Translucency 2. Yellow maize was degermed using a pilot-scale Beall-type degermer and the correlation between Translucency 1 and flaking grits > 3.9 mm was 0.67, $p < 0.001$.

The IA technique permits the non-destructive analysis of maize endosperm translucency on large samples of single kernels. It is suitable for rapid quantification of maize endosperm contents and predicting dry maize milling performance, as kernel translucency was significantly correlated with vitreousness in all instances. With further development of specific hardware and software, the technique has potential as an on-line maize kernel classification system in industrial mills. As the method is non-destructive, it is also suitable for classification of maize seed breeding material. It is also a potential method for the measurement of maize opacity as used by the wet milling industry, where opacity (the opposite of vitreousness) is related to maize starch yield.

UITTREKSEL

BEELDANALISE METING VAN MIELIEPIT LIGDEURLAATBAARHEID EN DIE VERWANTSKAP MET GLASIGHEID EN DROË VERMALINGSEIENSKAPPE

deur

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'n Vinnige nie-destruktiwe beeladanalise tegniek (IA) is ontwikkel vir die bepaling van mieliepit endosperm glasierheid. Pitte is met die Leica Q-Win Q500 IW-DX beeldanaliseerder toegerus met Leica Q-Win standard sagteware en 'n Sony XC-75 CCD kamera ontleed. Ligdeurlaatbaarheidsmetings van pitte is ge-optimeer deur gebruikmaking van 'n ligsisteen waar heel pitte bo-op ronde verligte oppervlaktes (sirkels) geposisioneer is. Die verligte gebied se oppervlaktes was kleiner as die geprojekeerde oppervlaktes van die pitte en die beligting is regdeur die pitte verkry. Korreksiefaktore is aangebring om konstante beligting van pitte met veranderde groottes op 'n konstante beligtingsoppervlakte te verkry. Korreksiefaktore is ook vir die effek van pitdikte op waargenome ligdeurlaatbaarheidswaardes ontwikkel.

Met behulp van handdisseksie is betekenisvolle korrelasie tussen gekorrigeerde ligdeurlaatbaarheidswaardes en glasierige sowel as ondeursigtige endospermopbrengste bevestig. Dit was: ligdeurlaatbaarheid as 'n persentasie van die heelpit (ligdeurlaatbaarheid 1) en glasierige endosperm (massa persentasie), $r = 0.77$, $p < 0.00001$ en ligdeurlaatbaarheid 1 en ondeursigtige endosperm (massapersentasie), $r = -0.72$, $p < 0.00001$ vir witmielies. Soortgelyke korrelasies is vir ligdeurlaatbaarheid as 'n persentasie van endosperm (ligdeurlaatbaarheid 2) gevind. Korrelasies is bereken nadat beide korreksiefaktore ingereken is.

In geval van geelmielies was Ligdeurlaatbaarheid 1 korrelasiekoëffisiënte van $r = 0.78$, $p < 0.00001$ en $r = -0.71$, $p < 0.00001$, met ooreenstemmende korrelasies vir Ligdeurlaatbaarheid 2, gevind. Korrelasiekoëffisiënte het betekenisvol toegeneem nadat pitdikte korreksies aangebring is.

Die IA tegniek is geëvalueer vir die voorspelling van die opbrengs glasige endospermprodukte tydens droë vermalingstoetse in die laboratorium en tydens industriële vermaling. Betekenisvolle negatiewe korrelasies is aangetoon tussen gekorrigeerde ligdeurlaatbaarheidswaardes en flottasie-syfers van heelmielies.

Betekenisvolle positiewe korrelasies is tussen gekorrigeerde ligdeurlaatbaarheidswaardes en vermalingsprodukopbrengste van glasige endosperm aangedui. Eksperimente met 'n laboratoriumskaal eksperimentele rollermeuletoets, sonder 'n kiemverwyderingstap (ontkiemer), het die volgende korrelasies opgelewer: tussen Ligdeurlaatbaarheid 1 en semolina opbrengs (massapersentasie), $r = 0.74$, $p < 0.001$ en Ligdeurlaatbaarheid 2 en semolina opbrengs (massapersentasie), $r = 0.70$, $p < 0.001$. 'n Bühler industriële-grootte mieliemeule is vir industriële proewe (drie ton per uur) aangewend. Die korrelasie tussen Ligdeurlaatbaarheid 1 en ekstraksie tydens ontkieming (produkoorloop) was $r = 0.93$, $p < 0.0001$. 'n Soortgelyke resultaat is vir Ligdeurlaatbaarheid 2 verkry. Geelmielies is m.b.v. 'n loodsaanleg Beall-tipe ontkiemer verwerk en die korrelasie tussen Ligdeurlaatbaarheid 1 en mieliegruis > 3.9 mm was $r = 0.67$, $p < 0.001$.

Die IA tegniek is geskik vir die nie-destruktiwe analise van mielie endospermiligdeurlaatbaarheid op 'n groot hoeveelheid enkelpit monsters. Dit is ook geskik vir vinnige kwantifisering van mielie endosperminhoud en droë vermalingspersentasie. Ligdeurlaatbaarheidsmetings is betekenisvol gekorreleer met glasigheid in alle gevalle. Die tegniek kan na verdere ontwikkeling van spesifieke harde- en sagteware vir 'n aan-lyn klassifiseringsstelsel tydens industriële vermaling aangewend word. 'n Besondere potensiële aanwending van die nie-destruktiwe tegniek is die klassifikasie van mielietelingsmateriaal. Dit is ook moontlik om mielie ondeursigtigheid ("opacity") as teenoorgestelde van Ligdeurlaatbaarheid) tydens natvermaling te evalueer vir voorspelling van mielietystelopbrengs.

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